Skills and Occupational Needs in Renewable Energy

2011

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Foreword

Moving towards a greener economy is creating opportunities for new technologies, investment and jobs. At the same time, environmental change and in particular climate change has detrimental effects on certain economic sectors and can cause job losses. Identifying and providing the right skills for new and existing jobs can smooth transitions to greener economies and ensure that new opportunities benefit a broader share of society. The shortage of green-collar professionals with cutting-edge skills in energy efficiency, green engineering and green construction has already been identified in a number of countries as a major obstacle in implementing national strategies to cut greenhouse gas emissions or address environmental changes.

In this context, the European Commission (EC) and the International Labour Organization (ILO) concluded a joint management agreement on *Knowledge sharing in early identification of skill needs for the low-carbon economy* with the aim of enhancing cooperation and knowledge-sharing in the field of early identification of skill needs. What each organization has learned from extending state-of-the-art knowledge and analysing good practices through this research programme will inform their own ongoing activities, not only in the EU but worldwide. This study was supported by the European Union Programme for Employment and Social Solidarity PROGRESS (2007–2013)[1] and matched the

[1] This programme is implemented by the European Commission. It was established to financially support the implementation of the objectives of the European Union in the employment, social affairs and equal opportunities area, and thereby contribute to the achievement of the Europe 2020 Strategy goals in these fields. The seven-year programme targets all stakeholders who can help shape the development of appropriate and effective employment and social legislation and policies, across the EU-27, EFTA-EEA and EU candidate and pre-candidate countries. For more information see: http://ec.europa.eu/progress

objectives expressed by the New Skills for New Jobs Initiative. For the ILO, the agreement supported the implementation of the Green Jobs Initiative, a partnership launched jointly with the United Nations Environment Programme (UNEP), the International Trade Union Confederation (ITUC) and the International Organization of Employers (IOE) in 2008.

Three mutually supportive global reports were produced under this joint management agreement:

- Comparative analysis of methods of identification of skill needs on the labour market in transition to the low carbon economy;
- Skills and occupational needs in green building; and
- Skills and occupational needs in renewable energy.

The studies build understanding of how to embark on a skills anticipation exercise for the low-carbon economy, which is relevant for national, sectoral and enterprise level human resource strategies in mitigation and adaptation to climate change. Two sectoral analyses identified global employment and skill needs trends in renewable energy and in green building.

The renewable energy sector is growing fast: about half of the new electricity-generating capacity added globally in 2008 and 2009 came from renewable energy additions. Different employment scenarios show that employment in renewable energy is expected to continue growing. This is contributing to an expected overall positive net employment growth in the energy sector as a whole while employment in fossil fuels is expected to drop in the coming years. Successful transition to a low-carbon economy, therefore, depends, among other things, on the accessibility of efficient training programmes: first, for current workers in fossil fuels to smooth transitions to the growing renewable energy sector, and second, for young people entering the labour market in the energy sector.

A commitment to training is particularly important because the renewable energy sector is already experiencing shortages not only in technical occupations such as solar installers and geothermal engineers, but also in more general occupations, such as sales and finance specialists, inspectors, auditors and lawyers. To make the most of investments in renewable energies, governments and social partners need to make sure that the workforce is adequately trained. One of the more challenging issues is the pace of change: the experience in some countries of surges in demand for skilled workforce during installation of new renewable energy capacities followed by drops in demand during its operation and maintenance is anathema to smooth transitions; it sends contradictory signals to workers and investors, as well as training institutions. Skills development systems need time to respond to the new needs and confidence that policies will sustain the transition and continue to create demand for new skills. An efficient training system for renewable energy must be integrated within overall policies to support the growth of the sector, involve social partners in the design and delivery of training, and include a good combination of practical and theoretical knowledge.

The *Study of occupational and skill needs in renewable energy* was prepared by an ILO research team consisting of Con Gregg, Jon Beaulieu and Mercedes Durán, under the leadership and coordination of Olga Strietska-Ilina and Christine Hofmann, and under the general supervision of the Director of the ILO Skills and Employability Department, Christine Evans-Klock. Jane Auvre provided administrative support throughout the project and assisted in publishing the reports.

The report draws heavily on research undertaken on behalf of the project by REN Alliance, in particular Werner Bussmann, Juliet Newson (International Geothermal Association), Cameron Ironside, Lau Saili, Kristin Schumann, and Greg Tracz (International Hydropower Association), Jennifer McIntosh, Paulette Middleton (International Solar Energy Society), Prof S.C. Bhattacharya, Karin Haara (World Bioenergy Association), and Martina Bacharova and Stefan Gsänger (World Wind Energy Association). The report also benefited from research undertaken by Tatiana Cyro Costa and Shinyoung Jeon. A number of experts provided comments at a focus group discussion in Geneva on 4 March 2011, and at the final technical validation workshop in Brussels on 29–30 March 2011, including Janet Asherson from International Organisation of Employers, David Boys from Public Services International, Isabelle Barthès from European Metalworker Federation, Brian Kohler from International Federation of Chemical, Energy, Mine and General Workers' Unions, Paula Mazzucchelli from European Renewable Energies Centres Agency , Martina Otto from UNEP, and Jerry Van den Berge from European Federation of Public Service Unions; and colleagues from the ILO: Carlos Carrion-Crespo, Ana Iturriza, Yasuhiko Kamakura, Larry Kohler, Lene Olsen and Ana Sanchez.

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Abbreviations

AWEA	American Wind Energy Association
BP	British Petroleum
CAGR	compound annual growth rate
CDM	Clean Development Mechanism
CEC	Clean Energy Council
Cedefop	European Centre for the Development of Vocational Training
CEGA	Andean Geothermal Centre of Excellence
CGE	computable general equilibrium
CLER	Comité de Liaison Énergies Renouvelables
COE	Center of Excellence
CSP	Concentrated solar power
DySAM	dynamic social accounting matrix
EC	European Commission
EER	Emerging Energy Research
EGS	Enhanced geothermal systems
EIA	Energy Information Administration
EMCEF	European Chemical Workers Federation
EPSU	European Federation of Public Services Unions
EREC	European Renewable Energy Council
ETF	European Training Foundation
EU	European Union
EURELECTRIC	Union of the Electricity Industry
GEA	Geothermal Energy Association
GHP	geothermal heat pumps

GT	gigatonnes
GWt	Gigawatt thermal
GW	gigawatts
GWh	Gigawatt hour
HVAC	heating ventilation and air conditioning
ICEM	International Federation of Chemical, Energy, Mine and General Workers' Union
ICT	information and communications technology
ICTSD	International Centre for Trade and Sustainable Development
IEA	International Energy Agency
IESE	Institute of Earth Sciences and Engineering
IGA	International Geothermal Association
IGZB	International Geothermal Centre of Excellence
IGCC	integrated gasification combined cycle),
IHA	International Hydropower Association
ILO	International Labour Organization
INET	Instituto de Educação Técnica
IOE	International Organization of Employers
IPCC	International Panel on Climate Change
ISES	International Solar Energy Society
ISP	The Institute for Sustainable Power
ITUC	International Trade Union Confederation
MW	megawatt
NABCEP	North American Board of Certified Energy Practitioners
NASA	North American Space Agency
NGOs	non-govermental organizations
NWPPA	Northwest Public Power Association
NZGA	New Zealand Geothermal Association
OECD	Organisation of Economic Cooperation and Development
PSI	Public Services International
RE	renewable energy
REN21	Renewable Energy Policy Network for the 21st Century
R&D	research and development
SAM	social accounting matrix model
SEIA	Solar Energies Industries Association
SRC	short rotation crops
SRREN	Special Report on Renewable Energy Sources
ST	solar thermal
TVET	technical and vocational education and training

TWh	terawatt hours
UNEP	United Nations Environment Programme
UK	United Kingdom
US	United States
USA	United States of America
WBA	World Bioenergy Association
WWEA	World Wind Energy Association

Executive Summary

Achieving a successful transition to the low-carbon economy is one of the greatest policy challenges of facing governments and their peoples worldwide, and is of deep concern to businesses, workers and the organizations that represent them. Reducing energy related emissions is central to this, as energy supply accounts for 25.9 per cent of carbon emissions. One of the keys to cutting energy-related emissions is to cut the carbon intensiveness of energy production by adopting renewable energy technologies.

In addition to contributing to the transition to the low-carbon economy, renewable energy also addresses wider issues of sustainability, such as reducing pollution, improving energy security and enabling access to energy by those who currently lack access to energy infrastructure.

The main renewable energy technologies are wind, solar, geothermal, hydropower and bioenergy. The report focuses on the skills required for these. Just 12.9 per cent of global energy supply comes from renewable sources, mostly from traditional combustion of biomass and from the relatively mature modern biomass sector, but more renewable capacity is being deployed rapidly. Almost half of the new electricity-generating capacity deployed globally in 2008 and 2009 was based on renewable energy technologies. Deployment of all the main technologies is growing strongly.

Despite ongoing technological improvements cutting the cost of producing renewable energy and opening up more renewable resources to exploitation, public policy still plays an important role in driving the deployment of renewable energy capacity, and will continue to do so.

Employment in renewable energy is not just located in the energy-producing sector. The renewable energy value chain encompasses: manufacture and distribution of renewable energy equipment; renewable energy project development; construction and installation work associated with the development of renewable energy capacity; operation and maintenance of renewable energy facilities; and a range of cross-cutting activities that contribute to more than one of the other value chain stages. Bioenergy has an additional value chain stage – growing and harvesting biomass.

The employment associated with any individual renewable energy installation is heavily front-loaded. Relatively large numbers of people are employed in construction and installation, project development and equipment manufacture. Once the installation is operating, much smaller numbers are required in operations and maintenance, although these jobs are most likely to continue to exist for the 20- or 30-year lifetime of the installation. Ongoing employment associated with a bioenergy installation is typically much higher than for other renewable energy technologies because of substantial employment in growing and harvesting biomass.

An important contribution that this report makes is a table (Table 4.1 in the main report) summarizing the core occupations in each part of the renewable energy value chain, for each technology, along with a description of the contributions they make. The table below shows an extraction from the main table for illustrative purposes, listing the main occupations associated with each stage of the value chain, but only for one technology under each value chain stage. Most of the occupations involved already exist, but require some new skills and knowledge.

Skills shortages in renewable energy appear to come about most frequently when a sharp increase in demand for skills appears. While the progression towards higher levels of employment in renewable energy appears fairly smooth when viewed at the global level, it can be far from smooth for a particular type of technology at the national or regional level. Employment in project development and in construction and installation is particularly vulnerable to booms and busts caused by faster or slower deployment of new capacity at the level of a country or region. Even with skills for operations and maintenance, employment tends to increase in jumps, which mean that periods of strong demand for additional skilled workers can be interspersed with periods of weak demand.

These patterns of demand for labour make it difficult for providers of education and training in skills relevant to renewable energy to match their activity to industry requirements. Skills strategies for renewable energy should be designed to mitigate this problem.

A key difficulty in ensuring an adequate supply of skills for renewable energy is that the sector requires substantial numbers of engineers and technicians. Shortages in these occupations are common in developed countries, and can easily occur in developing countries when there is a sudden increase in demand.

The main conclusions of the report are:

- Plans by governments and others to develop renewable energy projects require a skills component;
- Pacing investment in renewable energy to smooth employment over time can benefit renewable energy businesses and employees by preventing booms and busts in demand for skills;
- Smaller renewable energy projects require skilled crafts workers with sufficient breadth of skills to be able to do the work by themselves, or at least to cooperate effectively with others;
- There is a need for effective skills anticipation in renewable energy, and there is a particular need for developing countries to plan to maximize the local employment benefits of renewable energy projects;
- Initiatives to develop skills for renewable energy should aim to develop skills that are sufficiently portable so that they can be applied to new renewable energy technologies and outside the renewable energy sector;
- There is scope to provide internationally recognized industry certifications in renewable energy skills to complement national qualifications;
- There is a need for policy to focus on ensuring that the transition to renewable sources of energy is a Just Transition for those working in fossil energy sectors;
- There is a need for policy-makers promoting the transition to renewable energy to take account of Decent Work principles when designing policies and interventions;
- Large-scale renewable energy projects in developing countries should operate effective corporate social responsibility strategies;
- Social dialogue has an important role to play in the design and delivery of skills interventions for renewable energy; and
- There is a need for a range of initiatives to increase the supply of trainers.

Equipment Manufacture and Distribution	Project Development	Construction and Installation	Operation and Maintenance	Biomass production	Cross-Cutting Occupations
Wind • R&D engineers (computer, electrical, environmental, mechanical, wind power design) (H) • Software engineers (H,M) • Modellers (prototype testing) (H,M) • Industrial mechanics (M) • Manufacturing engineers (H) • Manufacturing technicians (M) • Manufacturing operators (L) • Manufacturing quality assurance experts (H,M) • Certifiers (H) • Logistics professionals (H,M)	**Solar** • Project designers (engineers) (H) • Architects (H) (small projects) • Atmospheric scientists and meteorologists (H) • Resource assessment specialists and site evaluators (H) • Environmental consultant (H) • Lawyers • Debt financier representatives (H) • Developers/facilitators (H,M) • Land development advisor (H) • Land use negotiator (H) • Lobbyist (H) • Mediator (H)	**Hydropower** • Engineers (civil, mechanical, electrical) (H) • Project managers (H) • Skilled construction workers (heavy machinery operators, welders, pipefitters etc.), (M) • Construction labourers (L) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)	**Geothermal** • Plant managers (H) • Measurement and control engineers (H) • Welders (M) • Pipe fitters (M) • Plumbers (M) • Machinists (M) • Electricians (M) • Construction equipment operator (M) • HVAC technicians (M)	**Bioenergy** • Agricultural scientists (H) • Biomass production managers (H,M) • Plant breeders and foresters (H,M) • Agricultural/forestry workers (L) • Transportation workers (L)	**From Solar** • Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M) • IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (Accountants, auditors and financers) (H)

Equipment Manufacture and Distribution	Project Development	Construction and Installation	Operation and Maintenance	Biomass production	Cross-Cutting Occupations
• Logistics operators (L) • Equipment transporters (L) • Procurement professionals (H,M) • Marketing specialists (H,M) • Sales personnel (H,M)	• Environmental and social NGO representatives (H,M) • Public relations officer (H) • Procurement professionals (H,M) • Resource assessment specialists (H)				• Health and safety consultants (H,M) • Clients (H,M,L)

The following coding is used to summarize the skill levels of occupations:
H = High skilled – Professional/managerial
M = Medium skilled – Technician/skilled crafts/supervisory
L = Low skilled – Semi-skilled and unskilled

Section 1

Introduction

1.1 Importance of renewable energy

Renewable energy is a major contributor to the transition to the low carbon economy. It also addresses wider issues of sustainability, such as reducing pollution, improving energy security and enabling access to energy.

The IPCC estimates that renewable energy accounted for 12.9 per cent of the total primary energy supply in 2008, and around 19 per cent of global electricity supply. Of the approximately 300 GW (gigawatts) of new electricity-generating capacity added globally in 2008 and 2009, 140 GW came from renewable energy additions. Traditional biomass (17 per cent), modern biomass (8 per cent), solar thermal and geothermal energy (2 per cent) together accounted for 27 per cent of the total global demand for heat. Developing countries already host 53 per cent of global renewable energy electricity generation capacity (IPCC, 2011).

This report addresses skills in the renewable energy sector as a whole. For those who have a particular interest in small-scale renewable installations, it should be read in conjunction with its companion report on skills in green building, as building scale renewable energy installations frequently form a part of green building projects.

Reasons for wishing to transition to renewable energy include the following.

- Energy supply is the sector with the highest greenhouse gas emissions. It accounts for 25.9 per cent of overall carbon emissions (IPCC, 2007). While renewable energy technologies emit some carbon over their lifecycle, it is far less than for fossil fuels.

- While the cost of electricity generated by renewable energy technologies is still frequently above that from fossil energy sources, long-run environmental benefits and energy security concerns make investing in renewable energy attractive to society as a whole. Many governments intervene with mechanisms to allow producers of renewable energy to capture economic returns based on the societal benefits.
- Replacing fossil fuels with renewable energy sources offsets pollution from combustion.
- Off-grid renewable energy solutions (meaning in areas not connected to a central grid) often already make economic sense without subsidies or policy support.
- In situations where the electricity grid is not reliable, renewable energies can serve as back-up systems (for example for hospitals), and can also stabilize electricity grids.
- Several renewable energy technologies are already competitive at market prices, depending on resource conditions and other factors. There is a long-run downward trend in the cost of energy from each renewable technology, which is likely to make renewable energy technologies in general more competitive with fossil fuel technologies over time.
- Concerns about future energy prices and energy security have increased interest in renewable energy investments.
- Decentralized electricity supply through renewable energies allows for mobilizing small-scale private investments in energy supply.

As a consequence, interest and activity in renewable energy is growing rapidly, both in developed and in developing countries.

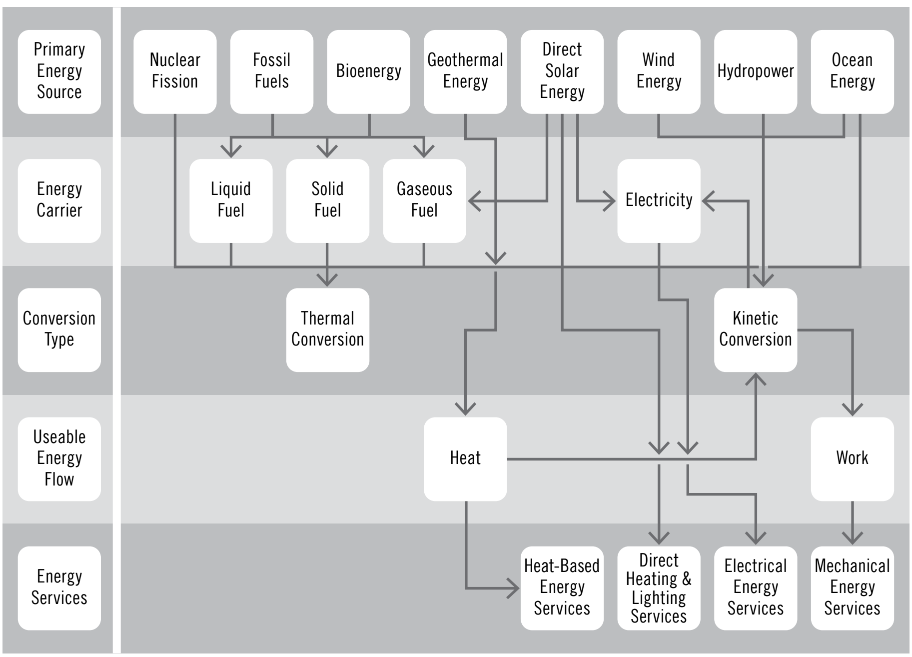
Developed countries are leading the effort in research and development. Policy support has led to high rates of investment, and growing numbers of people employed in the sector. For a number of important technologies, manufacturing is limited to a small number of developed and emerging economies. Emerging economies are rapidly catching up, and have surpassed developed countries in deployment and number of installed capacity in some areas.

Most developing countries still have low rates of deployment of renewable energy technologies, while in rural areas traditional use of biomass for cooking and heating remains important. Governments are only starting to put in place support measures for renewable energy. So far, much of the support for promoting new forms of renewable energy in developing countries comes from non-govermental organizations (NGOs) and international development partners. Technology imports remain expensive. Development of local capabilities and research and development to adapt renewable energy for local solutions is still in its infancy.

1.2 Renewable energy technologies

Primary energy sources are converted into energy services in a number of different ways, using different energy carriers (electricity or fuels), conversion types (thermal or kinetic) and usable energy flows (heat or work). Figure 1.1 provides an overview and shows how renewable energy sources are positioned alongside fossil fuels and nuclear fission. Renewable energies offer the full range of energy services – heat, light, electricity and mechanical energy.

Figure 1.1. Energy paths from primary energy sources to energy services



Source: IPCC (2011).

Different types of technology are applied to convert renewable energy sources into energy supplies.

Wind

Wind turbines are used to convert wind into electricity. A group of turbines forms a wind farm.

There are two main types of wind farm:

- Onshore wind farms where the wind farm is sited on land, typically in a place exposed to wind such as a hill top or coastal location; and
- Offshore wind farms where the wind farm is sited at sea.

Both types of wind farm require significant investment in site preparation, and to link the wind farm to the electricity grid. Offshore wind energy generally requires a larger investment to put a substantial foundation in place, and may cost more to connect to the electricity grid.

Small-scale wind turbines for domestic or local use are available, but are not a major presence.

Wind energy accounted for 0.2 per cent of global primary energy supply in 2008 (IPCC, 2011).

Solar

There are three main types of solar technology:

- Photovoltaic panels are used to convert sunlight directly to electricity.
- Solar thermal technologies are used to heat water.
- Concentrated solar power (CSP) technologies use mirrors to concentrate heat from the sun to heat water, with the heat then being used to generate electricity.

Many photovoltaic panels are installed at the level of the individual building, but they can also be installed in large numbers in a solar farm format.

Solar thermal technologies are focused on heating water for use in a building (hot water or heating) or for use in the locality.

Concentrated solar power plants are typically large-scale electricity generating installations connected to the electricity grid.

Direct solar energy accounted for 0.1 per cent of global primary energy supply in 2008.

Hydro

Hydropower converts kinetic energy from the gravity-driven flow of water into electrical energy by using it to drive generators. Large hydropower plants use turbines that are usually built into purpose-built river dams. Small hydropower plants may make use of a dam, or may use the flow of river water to drive a generator.

Hydropower accounted for 2.3 per cent of global primary energy supply in 2008.

Geothermal

Geothermal energy is used in two ways: either the heat is used directly in industrial processes or in heating buildings, or indirectly by using it to drive turbines to generate electricity.

Deep geothermal systems are based on drilling to reach hot rock, and using rock to heat water. Traditional systems rely on water and fractured rock already being present. Enhanced geothermal systems are an innovation based on pumping in water and fracturing the rock. Deep geothermal systems may have a substantial electricity-generating capacity. Shallow geothermal systems make use of modest temperature differentials, typically to heat (or sometimes cool) buildings.

Geothermal energy accounted for 0.1 per cent of global primary energy supply in 2008.

Bioenergy

The term bioenergy refers to energy derived from any organic matter that is available on a renewable basis. It may use any of a wide range of inputs, including forest and mill residues, agricultural crops and associated field as well as processing residues, wood and wood waste, animal excreta, aquatic plants, fast-growing trees and herbaceous crops, municipal and industrial wastes, among other sources.

Bioenergy outputs can include electricity, fuels such as bioethanol and biodiesel, and heat, with more than one of these sometimes coming from the same process. They can also include chemicals and other materials with potential for further processing.

Bioenergy uses a number of different types of process. The biomass may be burned directly to produce heat and/or fire the generation of electricity. It may go through a process to produce a liquid fuel such as biodiesel or bioethanol. It may go through a gasification process to produce gasses which can be stored and used to produce electricity. It may go through a process of anaerobic digestion to produce methane, which may then be used to generate electricity.

Biomass electricity generating plants are typically connected to the electricity grid. An important advantage to generating electricity from biogas or methane is that it is well suited to providing electricity at times of peak demand, while direct combustion of biomass is suited to base load generating technologies that produce a constant level of output.

The majority of biomass energy is still used in traditional applications such as fires to cook and warm homes, but the share accounted for by modern bioenergy processes is increasing rapidly.

Biomass energy accounted for 10.2 per cent of global primary energy supply in 2008. Modern biomass accounted for 38 per cent of this.

Ocean energy

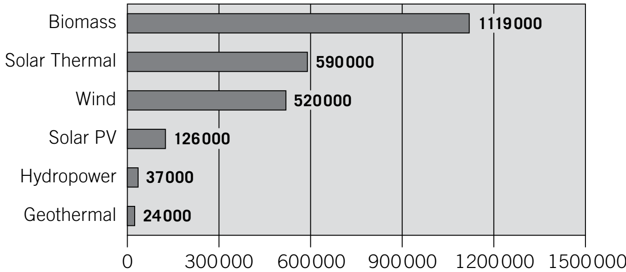
Ocean energy, including wave, tidal and ocean current power, is only moving towards commercialization now, and it is uncertain how it will develop. Its skills requirements are not addressed in this report.

1.3 Employment estimation and jobs prospects

Employment in the renewable energy sector has grown rapidly – in 2009 more than 3 million people worldwide were estimated to be working directly in the sector, about half of them in the biofuels industry, with additional indirect jobs well beyond this figure. The number of people employed in manufacturing, operation and maintenance of renewable energy facilities has more than doubled in countries such as Germany between 2004 and 2009. Solar photovoltaic offers the highest employment rate worldwide, with 7 to 11 jobs per megawatt (MW) of average capacity, which partly explains the high costs of this technology at present. This employment rate is likely to decrease alongside photovoltaic costs (UNEP, 2011).

Figure 1.2 indicates the estimated employment in the renewable energy industry, by country and by technology. China accounts for the largest number, with more than 1.12 million workers estimated in the renewable energy industry in 2008, with a growth rate of around 100.000 jobs per year.

Figure 1.2. Employment in renewable energy by technology in selected countries



China	1120000
Brazil	500000
USA	406600
Germany	278000
Spain	80940
Denmark	21000
India	10000

Source: UNEP (2011).

It has been estimated that, with strong policy support, up to 2.1 million people could be employed in wind energy and 6.3 million in solar photovoltaic by 2030, and around 12 million in biofuels-related agriculture and industry (UNEP, ILO et al., 2008).

According to the 2009 report *The impact of renewable energy policy on economic growth and employment in the European Union* (Fraunhofer ISI et al., 2009), total gross employment in 2020 will amount to 2.8 million jobs under an Accelerated Deployment Policy scenario which implies meeting the EU target of 20 per cent renewable energy share in energy consumption by 2020. The relative impact is expected to be larger for Eastern European countries, while in absolute figures countries with large populations such as Germany and France will benefit more. Net employment figures are much smaller but record positive employment effects.

1.4 Value chain

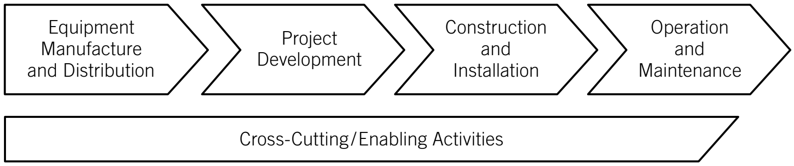
The renewable energy sector has four major elements to its value chain:

- Equipment manufacture and distribution
- Project development
- Construction and installation
- Operations and maintenance

The bioenergy subsector has a fifth major element to its value chain – growth, transport and processing of biomass.

In addition, there are cross-cutting and enabling activities that span all other elements of the value chain (see figure 1.3).

Figure 1.3. Renewable energy value chain



Source: Authors.

All renewable energy subsectors require substantial investment in capital equipment, which is supplied from equipment manufacturers. Examples include wind turbines, water turbines, solar panels and biomass digesters.

All substantial renewable energy projects involve an important project development phase in which the project is designed, planning and other regulatory permissions are sought, negotiations take place with regulatory authorities and often local residents are consulted.

Any substantial renewable energy project requires major investment in site preparation, installation and commissioning of the facility, and on most projects it is at this point in the value chain that by far the largest number of people is employed.

Once the plant has been installed and commissioned, it is necessary to operate and maintain it. Numbers employed are generally small relative to the construction and installation phase.

In most bioenergy projects, growing, processing and transporting biomass employs substantial numbers of people. Employment is typically less where the main source of biomass is some form of waste.

1.5 Sectoral coverage

In addressing skills throughout the renewable energy value chain, the subject matter of this report cuts across sectoral boundaries as defined in commonly used statistical systems.

In terms of ISIC Rev.4, the United Nations system of classification on which most others are based, relevant skills appear in at least the following sectors.

- Division 01, Crop and animal production, hunting and related service activities
- Division 02, Forestry and logging
- Division 09, Mining support service activities

- Division 24, Manufacture of basic metals
- Division 25, Manufacture of fabricated metal products, except machinery and equipment
- Division 27, Manufacture of electrical equipment
- Division 28, Manufacture of machinery and equipment n.e.c.
- Division 33, Repair and installation of machinery and equipment
- Division 35, Electricity, gas, steam and air conditioning supply
- Division 42, Civil engineering
- Division 43, Specialized construction activities
- Division 46, Wholesale trade;
- Division 49, Land transport and transport via pipelines
- Division 62, Computer programming, consultancy and related activities;
- Divisions 64–66, Financial and insurance activities
- Divisions 69–74, Professional, scientific and technical activities
- Division 84, Public administration and defence; compulsory social security
- Division 85, Education

1.6 Methodology

The research conducted for this report draws on findings from a survey among renewable energy associations, companies and training providers. This survey was conducted by REN Alliance, the umbrella organization of the five international renewable energy sub-sector associations: the International Hydropower Association (IHA), the World Wind Energy Association (WWEA), the International Geothermal Association (IGA Service GmbH), the World Bioenergy Association (WBA), and the International Solar Energy Society (ISES). The questionnaires are annexed to this report. REN Alliance produced a background report which builds the basis of the research. This was complemented by additional literature review. The report analyses data from 33 countries: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Ethiopia, Finland, France, Germany, Iceland, India, Ireland, Mexico, Mongolia, Nepal, Netherlands, New Zealand, Norway, Pakistan, Poland, Russia, Spain, Sweden, Switzerland, Thailand, Uganda, UK, USA, and Zambia.

The preliminary findings were validated through a focus group discussion in Geneva on 4 March 2011, involving representatives of Public Services International (PSI), the International Federation of Chemical, Energy, Mine & General Workers' Unions (ICEM), the International Organization of Employers (IOE), and different departments of the ILO.

The draft report was validated at a technical validation workshop in Brussels on 29–30 March which brought together representatives of the European Commission and the ILO, other international organizations such as Organisation of Economic Cooperation and Development (OECD), UNEP, European Centre for the Development of Vocational Training (Cedefop) and European Training Foundation (ETF), representatives of workers' and employers' organizations and of academia.

Drivers and Barriers

Section
2

2.1 Introduction

The renewable energy sector has the potential to deliver substantial reductions in energy related emissions of greenhouse gases and other pollutants, and a range of other benefits from improvements in energy security to boosting employment at a time of economic crisis.

This section of the report addresses:

- Climate change and the need for lower carbon emissions
- Increasing demand for energy
- Energy for developing countries
- Energy prices
- Market-based policy interventions
- Policy interventions
- Technological developments and productivity improvement
- Energy security
- Economic opportunities in renewable energy
- Need for jobs
- Lower barriers to market entry
- Barriers to renewable energy

2.2 Climate change and need for lower carbon emissions

Climate change and the global agenda to reduce CO_2 emissions are among the most pressing international challenges of the present day. Together they form the single most significant factor driving a preference for renewable energy over energy from fossil fuels.

About 84 per cent of current CO_2 emissions are energy-related and about 65 per cent of all greenhouse-gas emissions can be attributed to energy supply and energy use (IEA, 2010). About 41 per cent of energy related emissions are from the power generation sector.

Policy perspectives on how carbon emissions can be cut rely heavily on decarbonization of energy.

- The IPCC Special Report on Renewable Energy Sources (SRREN) reviews a large number of scenarios on stabilizing greenhouse gas levels, finding median renewable energy deployment in 2050 of 248EJ/year[2] to stabilize atmospheric CO_2 concentrations below 440 ppm, up from 64EJ/year in 2008[3].
- The International Energy Agency (IEA) sees decarbonizing the power sector as "crucial". Its Blue Map scenario, which describes a path to a 50 per cent reduction in energy-related CO_2 outputs by 2050, looks forward to a 90 per cent reduction in carbon emissions from the power sector relative to 2007, with almost half of all power generated then coming from renewable resources.

The most significant route through which this imperative to reduce carbon emissions impacts on the development of renewable energy is through shaping public policy. The IPCC report has shown that "it is not the availability of the resource but the public policies that will either expand or constrain renewable energy development over the coming decades". However, it notes that "the substantial increase of renewable energy is technically and politically very challenging".[4] Developments in how global warming is addressed politically, both in international relations and at national and subnational levels, will therefore have a major impact on the pace at which renewable energy solutions are deployed.

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[2] 1 Exajoule (EJ) $=10^{18}$ Joules.

[3] Of the 12.9 per cent of energy supplied from renewable resources in 2008, 6.3 per cent came from traditional use of biomass and 2.3 per cent from hydropower, both long established forms of renewable energy. Just 4.4 per cent came from the newer forms of renewable energy that account for most of the increase under the scenarios reviewed by the IPCC, so these figures reflect approximately an elevenfold overall increase in output of the newer forms.

[4] Press release on Special Report on Renewable Energy Sources, 11th Session of Working Group III, IPCC, 9 May 2011.

2.3 Increasing demand for energy

Demand for energy is growing rapidly. The IEA's *Energy technology perspectives* (2010) sees primary energy use rising by 84 per cent between 2007 and 2050 based on no change in policy. Even assuming strong energy efficiency measures, its Blue Map scenario sees primary energy usage rising by 32 per cent over the same period. These increases are driven primarily by rising living standards in developing and emerging countries, with people in these countries adopting lifestyles closer to the energy-intensive lifestyles of people in developed countries.

With demand for energy increasing, and with a constant need to replace and renew the existing stock of infrastructure as each plant reaches the end of its useful life, heavy investment in energy infrastructure would be essential even in the absence of concerns about global warming.

There is no issue as to whether large-scale investment in energy infrastructure is needed globally. The only real issue is about the composition of the investment.

2.4 Energy for developing countries

Another key driver of adoption of renewable energy technologies lies in enabling economic development and improving the standard of living in developing countries. Deployment of renewable energy technologies is necessary to reconcile the imperative to improve living standards in developing countries with stabilizing carbon emissions at a sustainable level.

However, the benefits to developing countries of deploying renewable energy technologies go beyond contributing to sustainability. They also provide practical solutions to challenges that developing countries face.

Currently 1.4 billion people globally lack access to electricity, restricting their access to clean lighting, to refrigeration, and to the information revolution. Technologies such as solar panels are being used to bring electricity to people without access to the electricity grid. Solar heating of water is also being deployed widely to bring hot water to homes and other buildings.

Existing electricity grids may be unreliable with occasional electricity cuts. Renewable energy can help stabilize grids, and provide back-up for particularly sensitive systems such as in hospitals.

In many cases, developing countries have access to renewable energy resources that are particularly suitable for exploitation.

- Many developing countries are in low latitudes well suited to the efficient exploitation of solar power, at levels from solar farm to domestic. This is most efficient in countries where there is little cloud cover, such as in North Africa.
- Significant numbers of developing countries are located in geologically active areas well suited to the exploitation of geothermal resources. In addition, some developing and emerging economies have exhausted oil wells that can be adapted to extract geothermal heat.
- Some developing countries have access to good wind resources that can be exploited efficiently with currently available technologies. Some with ocean coastlines have access to ocean energy resources that they may be able to exploit efficiently as ocean energy technologies mature.
- Most of the remaining unexploited sites suitable for hydropower are located in developing and emerging countries.
- While some bioenergy projects may compete with food security and with biological storage of carbon, there are significant opportunities available to developing countries for projects and initiatives without these problems. In addition to well chosen projects that include growing biomass, there are also opportunities based on exploiting biological waste and on improving the efficiency of traditional exploitation of biomass.

2.5 Energy prices

Concern about future energy prices is among the major factors motivating governments to favour renewable energy. Energy prices are volatile, and there is considerable uncertainty about their future path. Rapidly growing demand for energy and concerns about diminishing reserves in traditional sources have driven fossil fuel prices up. However, as oil prices have risen and shortages of gas have threatened, alternative fossil fuel sources[5] have come on stream, limiting the extent of price rises. While the use of these alternative sources of fossil energy is controversial because of their environmental impacts, their use is growing, causing uncertainty about future trends in energy prices and whether they will continue to be volatile.

Energy prices matter because, for many renewable energy technologies, the cost of producing energy over an installation's lifetime is still higher than the cost

[5] Including, for example, shale gas, shale oil and increased use of coal in some countries.

from other sources. While some technologies are broadly competitive with producing energy from fossil fuels, in many cases renewable energy's viability depends on a subsidy or mandate or on particularly favourable resource conditions.

In other cases, renewable energy is competitive because the infrastructure required to deliver energy from other sources is absent or deficient. For example, as noted earlier, there is significant activity in developing countries in deploying solar photovoltaic panels in locations that are off the electricity grid.

The cost of capital is also a major issue; while wind, sun and wave may be free, the cost of the capital equipment required to extract energy is high relative to that for fossil fuels, and the discount rate applied to capital invested can therefore be crucial to a project's viability.

The long run trend is for the real cost of energy from renewable technologies to fall over time, as innovations, economies of scale, investment in learning and the effects of competition accumulate. Bulges in demand can make prices rise above trend for periods, however. The IPCC quotes a number of examples, including the experience with onshore wind farms in Denmark where the cost per watt fell from US$2.6 in 1981 to US$1 per watt in 2004, with a subsequent bounce to US$1.4 per watt in 2009 (IPCC, 2011). The cost per watt of photovoltaic cells has fallen much more steeply over time, consistent with the long-term decreasing trend in the cost of silicon that also benefits silicon's information technology applications.

This has made renewable energy technologies progressively more competitive with fossil energy over time, widening the circumstances under which they can be deployed economically without subsidy or mandate, and reducing the incentive required under other conditions. Despite uncertainty about future fossil fuel prices, the combination of improving renewable energy economics and the policy imperative to stabilize emissions of greenhouse gases makes continuing growth in the deployment of renewable energy technologies much more likely than not, whether or not it is sufficient to meet targets agreed by the international community.

2.6 Market-based policy interventions

Because renewable energy technologies are not always cost competitive with other sources of energy, many governments wishing to make progress in decarbonizing their economies intervene in the market to favour energy from renewable sources. The ways in which they do this vary, and include favourable guaranteed minimum prices (such as technology-dependent electricity feed-in tariffs), remission on fuel taxes, subsidies, and mechanisms (such as emissions trading) to place a price on carbon emissions.

As businesses deciding to invest in renewable energy, and their financial backers, value certainty, governments frequently guarantee support for a number of years into the future. Where they anticipate that renewable energy costs will fall over time, governments may include planned reductions in the level of support they provide over time in their schemes.

These interventions are among the main mechanisms by which governments influence businesses to invest in renewable energy technologies that are not yet fully cost-competitive with other energy sources.[6]

2.7 Policy interventions

Governments also intervene directly to promote renewable energy, as illustrated by the following examples of types of intervention.

- Projects that will have a significant environmental impact are in many cases promoted in part by changing laws and regulations on land use priorities.
- In many cases, governments participate directly in large-scale projects, such as the construction of large scale hydropower facilities.
- Governments may participate by funding the development of necessary infrastructure, such as improvements to electricity grids.
- Governments also enforce joint ventures with foreign companies to facilitate technology transfer, development and local adoption.
- Governments sponsor students to study abroad and import technological know-how. For example, a successful solar photovoltaic entrepreneur in China studied and developed a patent in Australia (Barton, 2007).
- In many cases, governments provide public funds for research and development to support technology development.

[6] As another example, in some cases governments and regulators structure energy markets to the benefit of suppliers of renewable energy, resulting in costs being borne elsewhere. A number of renewable electricity technologies provide varying levels of output depending on variations in the resource. The more capacity of this sort that is supplied to the grid, the more other electricity generators have to be able to respond by increasing or reducing their output.

2.8 Technological developments and productivity improvement

Technological developments are among the most significant factors reducing the cost of renewable energy over time, and widening the range of ways in which renewable resources can be exploited. The amount of energy potentially available from wind, geothermal, ocean and solar resources far exceeds what is likely ever to be consumed. The constraint lies in the technologies used to capture and exploit it. There are more significant limits on the energy available from biological and hydropower resources, but there is still substantial scope for technological innovation and wider deployment of existing technologies to make more of this energy available.

Examples of developments that may have a significant impact include the following.

- If the long-term downward trend in the cost of photovoltaic panels continues, this is likely to transform the economics of solar generation of electricity, particularly in locations where there is a good solar resource.
- While wind turbine technologies are now quite mature, and the cost of equipment is falling relatively slowly, if innovations in construction significantly reduced the amount of concrete required for construction of offshore wind farms this could significantly reduce the cost of offshore wind.
- Enhanced geothermal systems (EGS), which are in the early stages of commercialization, have the potential to make geothermal resources exploitable under a much wider range of conditions than at present. Existing geothermal systems mostly depend on very favourable geological conditions where hot rock that can be reached by drilling is permeable and where water is already present (to produce hot water and steam). EGS technology exploits hot dry rock by pumping water deep underground, and promoting the formation of fractures.
- Bioenergy is a complex sector with a range of technological niches. It is a sector in which a considerable amount of innovation is underway, making new feedstocks available, and improving productivity and efficiency of conversion right along the value chain.

Arising from a combination of technological innovations such as these, and from more incremental improvements in productivity, it is likely that the inflation-adjusted cost per watt of renewable energy will continue to fall over the long run. For no change in the inflation-adjusted cost of energy obtained from fossil fuels, that would make renewables progressively more cost competitive over time.

2.9 Energy security

In addition to energy prices, many countries are concerned about security of access to energy, and security against rising energy prices in times of shortages. The ability to source energy from within their own national territory is a significant factor motivating countries to promote the deployment of renewable energy technologies. This has been reinforced by volatility in energy prices, particularly oil prices, associated with disruptions to oil output. In Europe, it has been reinforced in recent years by concerns about continuity in the supply of gas. These concerns have been reduced by the development of greater diversity in sources and routes of supply (enabled partly by growth in the transport of liquid petroleum gas by pressurized tanker), and by greater self-sufficiency in gas in North America.

More generally, many governments in developed, emerging and developing countries favour protecting their economies against disruption to international trade in energy and indeed against disruption to their economy's capability to pay for the energy it requires.

2.10 Economic opportunities in renewable energy

Economic opportunities are an important factor in persuading many governments to promote the deployment of renewable energy. These opportunities are of a number of kinds.

- Renewable energy provides major opportunities in developing technology industries. Countries such as Germany (photovoltaic panels) and Denmark (wind turbines) have invested heavily in supporting the development of these industries, directly or through providing demand for technologies in advance of their being fully viable commercially. With strong local demand, Chinese businesses are also coming to the fore in renewable energy technology industries.

  While many areas of renewable energy technology are now sufficiently mature so that it is difficult for new entrants to succeed in direct competition with existing international suppliers, others still provide opportunities for start-ups hopeful of dominating fast-growing market niches. Examples include wave energy and some newer and more niche-oriented technologies within bioenergy (such as use of algae to provide biomass).

- Some countries are particularly rich in resources suited to producing renewable energy. They may choose to use their renewable resources in preference to fossil resources for their own needs, but may also have an opportunity to export. This applies across all the major renewable technologies: countries with particularly good hydro, solar, geothermal and wind resources (and in future ocean resources too) may have a comparative advantage in producing electricity that will allow them to export successfully; countries with particularly good biomass resources may have a comparative advantage that will allow them to export bio-ethanol or biodiesel.

- For some countries, renewable energy provides an import substitution opportunity, although this is not as straightforward as it may appear initially. Assessing a project over its whole lifetime, it is necessary to offset the initial cost of imported technologies, ongoing payments to overseas suppliers (such as for maintenance and spare parts) and overseas financing costs, against savings in fuel imports when assessing the extent to which import substitution is real. For most countries, the share of total costs accounted for by imports will be lowest for projects that are relatively labour-intensive at construction/installation (for example hydro) and operations and maintenance stages (for example biomass production).

  Motivations for import substitution vary. Some countries are concerned with balance of payments issues, favouring local production of energy as a means of improving their balance of payments position. Other motivations include generating employment (see below) and developing local business.

2.11 Need for jobs

In countries with high levels of unemployment, whether this is a long-term issue or the immediate consequence of an economic crisis, generating employment opportunities is a major policy priority.

Developing renewable energy capacity can make a significant contribution to job creation. This has formed a significant part of the response to the economic crisis across much of the developed world. More generally, it is one of the benefits of exploiting the economic opportunities in renewable energy, potentially boosting employment in developing and emerging countries affected by significant unemployment and underemployment. For example, the Desertec Foundation's solar energy initiatives in North Africa have the potential to provide significant employment opportunities if they are successful.

The immediate employment impact of most renewable energy projects is strongly positive. There is substantial employment associated with project development, construction and installation for all renewable energy technologies. For countries that produce renewable energy technologies, there is also substantial manufacturing employment. While each individual project comes to an end, if there is a pipeline of new projects this can provide continuing employment for as long as the pipeline lasts.

Each renewable energy project leaves behind a much smaller number of jobs in operations and maintenance, but these accumulate over time as more projects are completed. Projects to install bioenergy capacity typically also leave behind substantial employment in biomass production, transport and processing.

Longer-term employment impacts of renewable energy are addressed later.

2.12 Lower barriers to market entry

A key factor shaping businesses and employment in renewable energy is that the barriers to entry into production of energy and generation of electricity have decreased. In most countries, these were highly regulated industries, mostly with high barriers to entry.

The mainstreaming of renewable energy has coincided with, and often contributed to, industry deregulation and changes in regulatory approaches. It has also reduced barriers to entry, making energy markets accessible to large numbers of new businesses. This has both shaped the structure of the energy sector, which has many more competing businesses than in the past, and accelerated the deployment of renewable energy, with many businesses seeking and exploiting opportunities as soon as they appear to be technologically and economically viable.

A number of factors have combined to allow this, including but not limited to the following.

- There is a widespread pattern of energy businesses becoming less integrated, with responsibility for activities in different parts of energy value chains being undertaken by separate businesses, where they were previously undertaken within integrated businesses.
- It has become relatively straightforward for businesses in many parts of the world with money to invest to purchase the equipment required to generate electricity from wind or sun, to contract in the skills required to develop, implement and manage a project, to purchase a suitable site, and to hire construction contractors to prepare the site.
- It is possible to purchase renewable generating capacity in smaller increments than with traditional large-scale fossil-fuelled power stations, steeply reducing

the minimum investment required to establish an electricity generating business.

- Governments and regulators have favoured the connection of renewable energy capacity to electricity grids. Several types of change have been common. Examples include: facilitating connection of smaller capacity generating facilities than in the past; and introducing market mechanisms for electricity suited to smaller suppliers. Supporting this has required, and continues to require, substantial investment in electricity grids, adding new grid connections and integrating "smart grid" technologies.
- Many governments have promoted the development of market outlets for renewable fuels, from subsidizing the installation of wood chip fired heating systems to subsidizing bioethanol or biodiesel, or mandating that vehicle fuels should include a minimum renewable content. Interventions such as these have provided market outlets for bioenergy businesses of all sizes.

Low barriers to entry have come in the context of considerable investor interest in infrastructure investment opportunities, particularly ones where the regulatory framework limits uncertainty.

2.13 Barriers to renewable energy

As highlighted by the IPCC, substantially increasing the use of renewable sources of energy is technically and politically challenging. Some issues include the following.

- With energy installations in many cases having a useful lifetime of 20 or 30 years, achieving the levels of deployment envisaged for 2050 by the IPCC, and by the IEA in its Blue Map scenario implies that a substantial share of all new energy installations globally should be renewable by 2020. If it is to be achieved, that will represent a very substantial shift in practice in a short time. Just for electricity, the Blue Map scenario assumes the installation of the equivalent of an average of 12,000 4MW onshore wind turbines, 3,600 4MW offshore wind turbines, 200 50MW biomass plants, 45 100MW geothermal installations, 325 million m^2 of solar panels, 55 250MW concentrated solar power plants and two to three 3 Gorges Dams of hydropower each year between now and 2050. Only hydropower and onshore wind are even approaching that rate of deployment at present. In the case of onshore wind, past expectations have been exceeded.

- The technological and infrastructural challenges are not limited to installing new capacity. Energy installations require considerable infrastructure to distribute their output. Putting that infrastructure in place requires both significant investment, and also cooperation with businesses involved in distribution. Where changes will be seen by end customers, their cooperation or acquiescence is required.
  - Those producing electricity have to be linked physically to the electricity grid. As many are installed in locations remote from existing high tension grid capacity, even physical connections require significant investment. Bringing larger numbers of generating stations online, and accepting substantial volumes of power that vary with supply conditions, requires significant changes to grid design and control systems.
  - Those producing fuels have to be linked into a distribution network. As the characteristics of renewable fuels are often different from those of the fuels they replace, this can create a need for new networks of distribution, or for existing networks to handle additional products alongside their existing ones. At the end of the distribution chain, there may be a need for consumers or businesses to invest in capacity to use the new fuel, such as a car that can run on an ethanol-heavy fuel mix or a wood chip burning stove.
- In some cases, renewable energy installations themselves have significant environmental impacts that may need to be balanced with their benefits, including visual impacts, impact on biodiversity and impacts on the local population. Alternative land and resource uses can also be an issue, particularly with bioenergy.
- Migrating from fossil energy to renewable energy will cause fossil-based energy industries to shrink, with impacts on economic activity and jobs. While the economic activity and associated jobs are replaced by activity and jobs in renewable energy, there are losers as well as winners. The businesses that succeed in renewable energy are often different from those that have been successful in fossil energy. While many of the skills required in renewable energy are similar to those in fossil energy, the jobs may be located too far away to be accessible. Moreover, in many cases renewable energy operations require fewer people in operations and maintenance, where much of the overlap in skills requirements is located, per unit of energy produced. This may result in opposition to the transition to renewable energy, particularly if insufficient effort is made to ensure that Just Transition principles are applied to protecting worker interests when planning and managing the transition within a country.

2.14 Conclusions

Activity and employment in renewable energy are moving forward rapidly chiefly because of policy interventions by governments designed to make progress on decarbonizing their economies by increasing the share of energy that comes from renewable sources. This transition is being facilitated by developments in renewable energy, ranging from major technological innovations to more incremental improvements in productivity.

The benefits to energy security arising from using locally available energy resources are also a factor. Another significant factor is that impacts on employment influence policy to a significant extent, both from the perspective of the immediate jobs boost that investment in renewables can provide, and from the perspective of potential job losses at renewable energy businesses.

Section

3

Trends in Renewable Energy and its Subsectors

3.1 Introduction

This section deals with trends in the renewable energy sector. It introduces general considerations about the value chain in renewable energy, and employment trends and dynamics that are relevant for skills development policies and systems.

Sections 3.3–3.7 present the background, value chain, growth and employment trends for each subsector of renewable energy.

3.2 Patterns of employment in renewable energy

3.2.1 Introduction

This section addresses patterns of employment in renewable energy under two headings: employment dynamics and Decent Work.

3.2.2 Employment dynamics in renewable energy

In considering employment and skills in renewable energy, it is necessary to take account of the dynamics of employment.

Patterns of employment in manufacturing and distribution of renewable energy technologies are broadly similar to those in other capital investment goods industries. With a substantial share of sales going to export markets, businesses are cushioned against local variations in activity. The amount of business they obtain, and hence the amount of employment they can support, is essentially a function of global market conditions and of the share of the market that their competitiveness allows them to take.

Patterns of employment in project development and in construction and installation are quite different. Work is project-based, and so continuity of employment depends on a fairly steady flow of projects. Highly skilled people who are internationally mobile may be able to achieve this continuity by moving to wherever the work is available. Those expecting to work in their home region depend on a steady stream of project work within that area, which may not occur unless it is planned.

This is an important issue for businesses too. It is not in their interest to alternate between booms in activity when they have difficulty recruiting enough people, and busts when they may lose skilled people to other sectors where steadier work is available.

When deployment of a renewable energy technology first starts in a region, it takes time to build up a supply of people with both the broad skills required and the experience and specific knowledge needed to apply them effectively. A gradual ramp up in activity is less likely to run into serious problems with skills supply than an attempt to deploy the technology at full speed from the start.

Patterns of employment in operations and maintenance are more stable. A renewable energy installation may have a 20-year or 30-year lifetime, and more if the equipment is renewed. It will have to be operated and maintained over its working lifetime, and while there may be some improvement in productivity over the period there is a reasonable prospect that most of the jobs that exist after commissioning will still exist a couple of decades later.

Employment in operations and maintenance tends to increase in jumps. When a significant new installation is commissioned, there is then a need to employ people to operate and maintain it.

In biomass production, once the biomass plant is in operation and can operate economically, demand is likely to be fairly steady. Changes in employment after that are most likely to arise from improvements in productivity, which may arise if more efficient machinery (including harvesting machinery) is introduced.

The employment dynamics just described are mostly relevant to projects of significant size. Where a renewable energy sector instead relies on large numbers of small renewable energy projects, such as in installing solar technologies at the level of a building, the volume of work to be done is likely to change more smoothly over time, making demand for workers less volatile.

3.2.3 Decent Work considerations in the renewable energy sector

Some studies provide insights about the quality of jobs in the renewable energy sector. There are jobs that can be labelled green but not decent, for example poorly remunerated day labourers on biofuels plantations working under hazardous conditions. In Brazil, for instance, the working conditions of many of the cane cutters for bioethanol production in São Paulo state are reported to be poor. Despite improvements implemented by employers and strengthened government regulation, the length of their working life is reported to be about 10–15 years because of extreme physical efforts (Zafalon, 2007). Examples of green and decent jobs would, for instance, be unionized wind and solar power jobs. Since many enterprises in the renewable energy sector are relatively young, the degree of unionization in the industry still tends to be lower than in other sectors. A challenge to union representation is that workers in the sector are affiliated to a large variety of different trade unions, as the sector cuts across several sectors (metal, construction, service and so on) which may historically have been organized separately, by different trade unions.

Studies in Germany and Spain indicate that qualification levels of workers in the renewable energy sector exceed the average qualification level of the workforce. The study undertaken by the Fundación Biodiversidad and Observatorio de la Sostenibilidad en España (2010) indicates that the level of training for workers in renewable energy in Spain is higher than in the rest of the economy. Fifty per cent of the sector's employees have university studies and 29 per cent have vocational education and training, in comparison with 23.5 per cent university graduates and 18.6 per cent vocational training graduates for the rest of the Spanish economy. In addition, the identified recruitment needs in the country in the short-term are 60 per cent of university and 33 per cent of vocational training graduates.

Higher qualifications may explain the higher wages paid to renewable energy workers in some parts of the world. For example, many jobs created by the wind industry in the North Sea are reported to be highly skilled positions with high pay. In addition, job quality in this industry is generally acknowledged to be less hazardous than in some non-renewable energy industries, such as coal mining (Esteban et al., 2010).

Renewable energy industries also employ people in semi-skilled and low-skilled occupations who earn lower wages: for example, low-skilled workers involved in the construction of facilities or farm workers in bioenergy projects. In the United States, wages in wind and solar manufacturing in some regions have been lower than the national average for the manufacture of durable goods (Good Jobs First, 2009). Still, a Canadian study indicates that opportunities for training and moving up the occupational ladder are more widely available in green energy jobs than in low-paid service-related jobs. The study concludes therefore that "the green investment agenda will, relatively speaking, expand decent employment opportunities even among people who are initially employed on green projects at low pay" (Pollin and Garrett-Peltier, 2011).

Permanent employment contracts in the renewable energy sector seem to be common in Spain, one of the leading countries in renewable energies. The study undertaken by the Fundación Biodiversidad and Observatorio de la Sostenibilidad en España (2010) shows that permanent and full-time employment in renewable energies makes up 94.9 per cent of the renewable energy employment in the country, compared to 65 per cent of permanent and full-time jobs in the whole Spanish economy.

Jobs stability, however, largely depends on a subsector. In Portugal, for instance, the majority of jobs created through a large wind power investment project were found to be temporary (Prata Dias, 2010). This can be explained by the fact that operation and maintenance of wind power plants requires less labour input than the development and implementation phase of renewable energy projects. Jobs for workers involved in construction and installation therefore will only be maintained if a constant level of investment in renewable energy is secured, which means increasing market shares for renewable energy provision. In Germany, the share of temporary workers (7.4 per cent) in the renewable energy sector is three times that of the overall share of temporary workers in the German economy (2.5 per cent). In the hydropower sector, operators or equipment maintainers are often public employees with a job for life.

A study by the European Agency for Safety and Health at Work identifies new and emerging risks to occupational safety and health associated with new technologies in green jobs. It points out that skill shortages in emerging green sectors may be met by migrant workers who are often employed in more precarious conditions and receive less training. As a consequence, they can be exposed to greater work-related risks (Ellwood et al., 2011).

When it comes to gender balance in renewable energy, research in Germany indicates that the percentage of women in renewable energy is only 23.6 per cent, much lower than the percentage for the whole economy, which is 45 per cent. Yet this share equals the percentage of women in the energy and water supply sector as a whole: 24 per cent. This reflects a pattern that women are typically under-represented in the energy sector (including in renewable energy) because many of the jobs are in engineering and durable goods manufacturing. Even so, women can benefit from renewable energy deployment in developing countries. In rural Bangladesh and Kenya, women work as solar panel installers and technicians (Way et al., 2010). Decentralized energy generation from renewable sources in rural areas poorly served by electricity grids can reduce the amount of work to be done by women in tasks such as collecting firewood.

3.3 Wind

3.3.1 Background

Wind energy has been used for centuries to provide mechanical energy, but has only recently become a major source of electrical power. Traditional uses for mechanical energy derived from wind include driving mills and pumping or lifting water among others.

The rapid growth in wind energy currently underway is based on using wind turbines to generate electricity. Commercial scale operations group turbines together in wind farms (from several to several hundred), and produce power that is fed into the electricity grid.

Wind farms are generally located in places with a good wind resource – typically on hills, at the coast or at sea. Wind power generated from turbines on land is known as onshore wind. That generated from turbines at sea is known as offshore wind.

To date, most wind power generating capacity has been deployed onshore. Deploying wind turbines at sea usually costs more.

3.3.2 Value chain

The main phases of the wind value chain are shown in table 3.1.

3.3.3 Trends in sector growth

Key figures for the wind sector are set out in table 3.2.

The wind power sector has grown strongly worldwide over the past two decades. As may be seen in figure 3.1, total installed capacity reached 159 GW by the end of 2009. By the end of 2010 almost 200 GW of capacity was installed. The

Table 3.1 Wind value chain

Equipment Manufacture and Distribution	Project Development	Construction and Installation	Operation and Maintenance	Cross-cutting/ Enabling Activities
• R&D (e.g. materials, componentry • Component design and manufacture (e.g. blade, tower, nacelle, generator) • Modelling and testing (e.g. prototype development) • Raw materials supply • Assembly • Quality assurance • Certification • Marketing Sales • Delivery	• Wind farm design • Wind resource assessment • Environmental and social assessment (birds, visibility, water, etc.) • Land agreements • Economics and financing • Permit application, monitoring and amendment • Power purchase agreement and grid connection contract • Selection of supplier	• Infrastructure development • Turbine erection and commissioning • Grid connection	• Operation and maintenance • Financial management • Repowering (or removal)	• Training • Policy-making • Management and administration • Insurance • IT • Health and safety • Financing • Communication

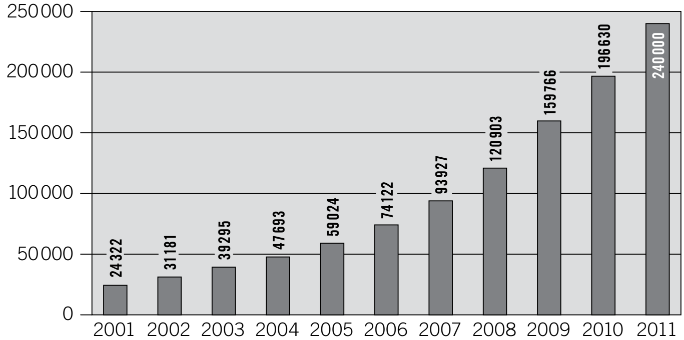
Source: Authors.

Table 3.2 Key figures for the wind sector

	Wind
Total installed capacity in 2010 (WWEA, 2011)	197 GW
Percentage of the global primary energy supply in 2008 (IPCC,2011)	0.2
Gross electricity generation in 2008 (EIA, 2011)	218,504 GWh*
Capacity growth 2008–2009 (IPCC, 2011)	32 per cent increase
Capacity added in 2009 with respect to 2008 (IPCC, 2011)	38 GW added

* Gigawatt hour.

Figure 3.1. World total installed wind capacity



Source: WWEA (2010).

expected capacity for the end of 2011 is 240 GW (WWEA, 2011). In 2001 total installed capacity worldwide was about 24 GW.[7]

Wind power received more than 60 per cent of utility scale renewable investment in 2009 (excluding small projects), due mostly to rapid expansion in China (REN21, 2010).

Wind now contributes roughly 2.5 per cent of the world's electricity (WWEA, March 2011). The IEA projects that under the Blue Map scenario 12 per cent of global electricity will be from wind energy by 2050, and 2,000 GW of capacity will mitigate emissions equivalent to 2.8 gigatonnes of CO_2 annually.[8]

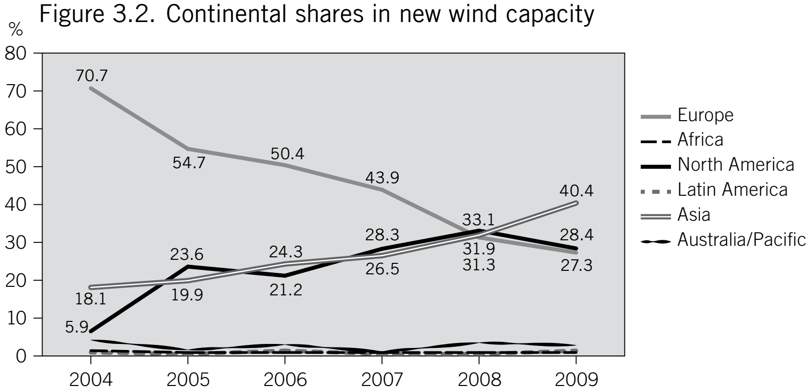
Installed wind capacity is more than doubling every three years. The number of countries using wind energy on a commercial basis was 83 at the end of 2010 (up by one from 2009), out of which 52 countries had increased their installed capacity during the year.

While there has been a slowdown in new installations in some countries, probably associated with the recession (WWEA, October 2010), there has been rapid growth in capacity in leading countries, such as China, Germany, India, Spain and the United States. Europe still plays an important role in the wind energy market, although the countries that have the biggest capacities for 2009 are China and the United States (see figure 3.2). These two countries have become the largest markets for new wind turbines, and together they represent 38.4 per cent of global wind capacity.

[7] Not included in table 3.2 as data is not final, and so as to maintain consistency between "Key figures" tables for each renewable energy technology in this section of the report.

[8] The Blue Map scenario envisages a need for investment US$46 trillion higher than the Baseline scenario to 2050. Consumers invest in more energy-efficient equipment, buildings, vehicles and industrial plants with carbon capture and storage (CCS), and electricity generators invest in more capital-intensive renewables, nuclear and CCS-equipped plant.

Figure 3.2. Continental shares in new wind capacity



Source: WWEA (2010).

Wind power remains unequally distributed around the world, because of differences in public policy, differences in the available wind resource, challenges with financing (especially in least developed countries) and a lack of adequately qualified manpower in many areas.

Offshore wind capacity is growing, with Europe being the leading generator of offshore wind electricity (WWEA, 2011). By the end of 2010, 12 countries had offshore wind farms, ten of them in Europe plus some minor installations in China and Japan. Total installed offshore wind capacity amounted to 3.12 GW. The share of offshore in total wind capacity worldwide went up from 1.2 per cent in 2009 to 1.6 per cent in 2010. The rate of growth in offshore wind is slightly below the general growth rate for wind power.

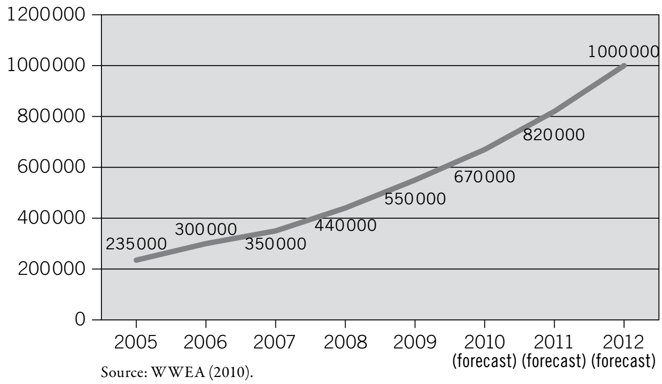
In 2004, Europe still accounted for 71 per cent of the market for new wind turbines, but the market has become more diversified. In 2009, Europe's share dropped to 27 per cent, while Asian markets accounted for 40 per cent of the new wind turbines installed during that year. The market continues to grow, and diversify further. Currently, manufacturing remains concentrated in a small number of countries: China, Denmark, Germany, India and Spain.

In 2010, the Chinese wind market grew to represent more than half of the world market for new wind turbines, adding 18.9 GW, 50.3 per cent of new capacity installed. Capacity continued to grow quickly in the United States, growing by 5.6 GW in 2010, after growing by 9.9 GW in 2009.

3.3.4 Employment trends

The wind energy sector has become a significant source of employment. Jobs have more than doubled from 235,000 in 2005 to 550,000 in 2009 (WWEA, 2010). The number of jobs is expected to increase further reaching about one million by 2012 (figure 3.3). The *Green jobs report* (UNEP, ILO et al., 2008) estimated that, with strong policy support, up to 2.1 million people could be employed in wind energy by 2030.

Figure 3.3. Wind energy jobs worldwide



Source: WWEA (2010).

3.4 Solar

3.4.1 Background

A non-exhaustive list of solar energy applications includes solar electricity, solar hot water, solar thermal collectors in central heating systems, potable water via distillation and disinfection, day lighting, solar cooking and high temperature process heat for industrial applications.

Solar technologies are broadly characterized as either active solar or passive solar depending on the way they capture, convert and distribute solar energy. Active solar refers to the use of photovoltaic panels and solar thermal collectors to capture energy. Passive solar include techniques mainly focussed on orienting a building to the sun, selecting materials with favourable thermal mass or light dispersing properties, and designing spaces that circulate air naturally. The focus of this report is on active solar.

The active solar energy business sector is composed mainly of photovoltaic and solar thermal, with applications ranging from individual small-scale installations to large-scale utility applications. Concentrated solar power (CSP) technologies are also becoming significant. These use mirrors to concentrate heat from the sun to heat water, with the heat then being used to generate electricity.

3.4.2 Value chains

Active solar involves production and installation of photovoltaic and solar thermal capacity in addition to the new area of concentrated solar power (CSP). In broad terms, its value chain is similar to that in other renewable energy sectors, although there are differences in the activities within each stage.

Solar projects range from very small in scale (such as installing a solar water heating system or a solar panel to supply a single home with hot water or electricity), to very large (such as an extensive solar farm composed of hundreds of photovoltaic panels or a large concentrated solar power facility).

The solar value chain is shown in table 3.3.

Table 3.3 Solar value chain

Equipment Manufacture and Distribution (only for active solar)	Project Development	Construction and Installation	Operation and Maintenance	Cross-cutting/ Enabling Activities
• R&D • Design and manufacture of components, solar panels and other equipment • Modelling and testing • Quality assurance and quality control • Marketing • Sales • Delivery	• Solar system/farm design • Site assessment (shadows, radiation, etc.) • Environmental and social impact assessment • Land agreements • Economics and financing • Permitting • Power purchase agreement and grid connection contract • Selection of supplier (only for active solar)	• Construction of solar system/ farm • Solar panels installation • Quality assurance and quality control • Grid connection	• Operation and maintenance • Recycling*	• Training • Policy-making • Management and administration • Insurance • IT • Health and Safety • Financing • Communication

* Recycling is a more immediate issue for the solar subsector than for other parts of the renewable energy sector because specialized facilities are required to recycle photovoltaic panels that are broken or past the end of their useful life.

Source: Authors.

An important feature in the supply of photovoltaic panels is that while Europe accounted for 81 per cent of demand in 2010, it only accounted for 17 per cent of supply. China and Taiwan Province of China together accounted for 56 per cent of supply, estimated to increase to 60 per cent in 2011 (Navigant Consulting, 2011).

3.4.3 Trends in sector growth

Key figures for the solar sector are set out in table 3.4.

The solar sector has experienced rapid growth in recent years, with strong growth and investment across the sector. Grid-connected solar photovoltaic has grown by an average of 40 per cent per annum since 2000 and it has significant potential for long-term growth in almost all world regions. Even in recent post-crisis years of 2008–2009, there was growth of 53 per cent. Solar hot water grew by 19 per cent per annum from 2005 to 2009 (21 per cent between 2008 and 2009; REN21, 2010).

By 2050, photovoltaic global cumulative installed capacity could reach 3,000 GW, providing 4,500 terawatt hours (TWh) of electricity per year (that is, around 11 per cent of global electricity production). In addition to mitigating

Table 3.4 Key figures for the solar sector

	Solar
Total installed capacity in 2009 (REN21, 2010)	21 GW for Solar Photovoltaic, Grid-connected 0.6 GW for Concentrating Solar Thermal Power 180 GWth* for Solar Collectors for Hot Water/Space Heating
Percentage of global primary energy supply in 2008 (IPCC, 2011)	0.1
Gross electricity generation in 2008 (EIA, 2011)	898 GWh for Solar Thermal 12,016 GWh for Solar Photovoltaic
Capacity growth 2008–2009 (IPCC, 2011)	53 per cent increase for Grid-connected Photovoltaic 21 per cent increase for Solar Hot Water/Heating
Capacity added in 2009 with respect to 2008 (IPCC, 2011)	7.5 GW added for Grid-connected Photovoltaic 31 GW added for Solar Hot Water/Heating

* Gigawatt thermal.

2.3 gigatonnes (Gt) of CO_2 per year, this level of photovoltaic would deliver substantial benefits in energy security and socio-economic development (IEA, 2010).

Indications are that this growth will continue, although this will depend to some extent on the pace at which incentives for photovoltaic panels are wound down as their economics improve. The sector is still early in its lifecycle, and technological advances are making photovoltaic and concentrated solar power technologies more competitive. Change is occurring rapidly in the sector.

Some countries and regions are experiencing pockets of very rapid growth while other areas within the same country are showing much slower growth. For example, in the United States, state level efforts to increase the use of solar power vary considerably.

3.4.4 Employment trends

In the solar energy sector, direct jobs are growing. REN21 estimates there are currently 300,000 jobs in solar hot water, 300,000 jobs in photovoltaic and around 2,000 jobs in solar thermal power. The Green Jobs report's estimate for solar thermal was higher than this at 624,000 for just four major countries (China, Germany, Spain and the United States). Given rapidly rising interest in solar energy alternatives and expected production growth, future years may well see worldwide employment soar – to possibly as high as 6.3 million in solar photovoltaic alone by 2030 (UNEP, ILO et al., 2008).

As an example, a 2010 report on the United States identified more than 93,000 solar jobs. In addition, the report found that solar employers expected to increase the number of solar workers by 26 per cent, representing nearly 24,000 net new jobs, by August 2011 (SEIA, 2010).

Jobs in installing, operating and maintaining solar energy systems are local in nature and therefore mostly occur in the country where the capacity is installed. Kenya, for example, has one of the largest and most dynamic solar markets in the developing world.

3.5 Hydropower

3.5.1 Background

The term "hydropower" encompasses power derived from moving water and the technology utilized to harness it. Kinetic energy from water, flowing by gravity from higher to lower elevation is converted into mechanical power through a device, usually a turbine. Hydro mechanical power has been used since antiquity. However, hydroelectric power is the principal modern form of the technology, developed from the late nineteenth century.

Hydropower projects may be categorized by the way they harnesses water to generate power as follows:

- Hydrokinetic: a project which places devices capable of generating electrical power from the flow of water in a watercourse;
- Run of River: a project which utilizes a watercourse to pass water through a power plant with limited storage;
- Reservoir: a project which impounds a watercourse for storage (forming a reservoir), for release through a power plant;
- Pumped Storage: a project which pumps water from a lower level to a reservoir at a higher elevation for storage in a cyclical fashion, for release through a power plant (at times of high demand).

The industry, at the international level, does not distinguish between or track "large" and "small" hydropower separately. These categories are sometimes used by policy-makers at the national level, and definitions vary widely according to socio-environmental and financing support policy choices.

Policy interest in hydropower can be explained partly by the way it complements variable sources of electricity including wind and photovoltaic. Its output can be varied to compensate for variations in output from variable sources. In addition, it can help to maintain stable power systems, storing energy, and (as a renewable source itself) help meet climate change mitigation targets and adaptation objectives. Hydropower reservoirs can also be used to provide water management services, which have an important role in adapting to changing patterns of rainfall arising from climate change.

Hydropower's role in climate change mitigation and adaptation is due to the high power density to carbon footprint of the schemes, which has given hydropower a relatively important share of the Clean Development Mechanism

(CDM).[9] Of the 2,786 CDM projects registered in 2010, 30 per cent were hydropower projects (UNEP, 2011).

The relatively long, well-developed history of hydropower deployment and technological advancement means hydropower development has been well documented and studied. In the past two to three decades, the industry has developed an emphasis on environmental and social performance, often as much as or more than technical and cost considerations. This has required new resources and skills in environmental and social impact assessment, and in managing relationships with stakeholders.

Strong role of public sector

Economies of scale mean that larger projects are often more viable than smaller ones – producing some of the most cost-effective electricity of any energy technology, fossil fuel, nuclear or renewable, as may be seen in table 3.5. Cost variations between countries and variations between hydropower sites mean that development costs for a project of a given size can vary considerably.

The large upfront capital cost and longevity of hydropower assets means that the public sector has had, and continues to have, a strong role to play in hydropower development – whether directly, or through national, bilateral or multilateral funding arrangements. The longevity of hydropower facilities also means that operations and maintenance employees of hydropower generators often have secure permanent employment.

Table 3.5 Costs of hydropower development

Project size (MW)	Development cost (US$million/MW)	Operational cost (US$/MWh)
< 10	1 to > 5	3 to 10
10 to 100	1 to 3	3 to 7
> 100	1 to 2.5	3 to 7

Source: Taylor (2010).

[9] Under the Clean Development Mechanism, emission-reduction (or emission removal) projects in developing countries can earn certified emission reduction credits. These saleable credits can be used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol.

3.5.2 Value chain

Most employment in the hydropower's value chain is project oriented. The highest levels of employment are at the project development and construction, manufacturing and installation phases. Once a project reaches the operational phase, labour levels decrease dramatically. If there are no or few new projects in train within a country or region, skills and training needs diminish, with few people needed to work in project development, construction and installation. Ongoing demand for new people to work in operations and maintenance will be modest, as numbers will not be growing and the number of existing people needing to be replaced will generally be low.

The hydropower value chain is shown in table 3.6.

Table 3.6 Hydropower value chain

Equipment Manufacture and Distribution	Project Development	Construction and Installation	Operation and Maintenance	Cross-cutting/ Enabling Activities
• R&D • Design and manufacture: turbine; generator and excitation; other hydro-mechanical components (e.g. valves, penstocks); other electrical components (e.g. transformers, power, electronics etc.); governor and control systems • Quality assurance • Marketing and Sales • Delivery	• Design • Site investigations and feasibility studies • Insurance • Environmental and social assessments • Land agreements • Financing • Licensing/ Permitting • Selection of supplier	• Project construction • Project commission	• Routine operation and maintenance • Minor equipment overhauls • Major equipment overhauls	• Training • Policy-making • Management and administration • Insurance • IT • Health and Safety • Financing • Communication

Source: Authors.

3.5.3 Trends in sector growth

Key figures for the hydropower sector are set out in table 3.7.

Hydropower has been booming alongside the other renewables since the turn of the millennium. While the growth rates are not as high comparatively as for wind or solar photovoltaic, for example, 2008 was a record year for new capacity deployed out of the entire history of hydropower development.

Global installed capacity for hydropower grew by an average of 27 GW/year over the past five years, a growth rate of approximately 3 per cent per annum and 31 GW increase in 2009 with respect to 2008 – with higher per annum growth in smaller-scale (less than 0.05 GW) projects of approximately 9 per cent.

In 2008, hydropower provided about 3,300,000 GWh (figure 3.4), 16 per cent of the world's electricity generation, equating to 86 per cent of renewable energy-sourced generation (EIA, 2011). In 2008, hydropower represented 2.3 per cent of global primary energy supply, and 16 per cent of global electricity supply (IPCC, 2011). Hydropower is currently generating electricity in some 160 countries utilizing more than 11,000 stations with around 27,000 generating units (Taylor, 2010).

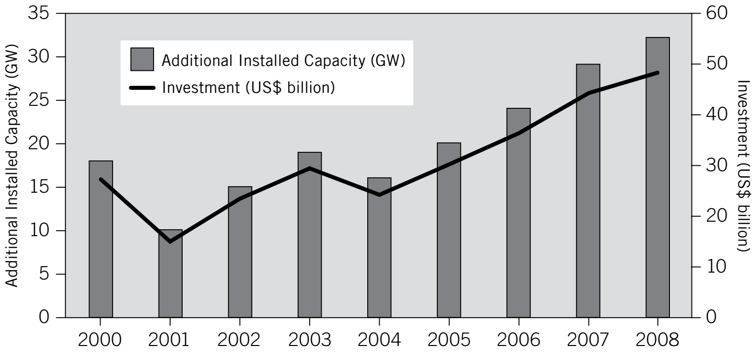
Since the mid 1970s, hydropower deployment has been reflecting globalized patterns of development, with growing capacity in the Asia Pacific and South and Central Americas, as may be seen in figure 3.5.

There has been a substantial shift in deployment growth from developed countries to emerging and developing countries between the mid-1970s and today. Growth in developing country deployment has been particularly concentrated in Asia and Latin America where the majority of the world's hydropower

Table 3.7 Key figures for the hydropower sector

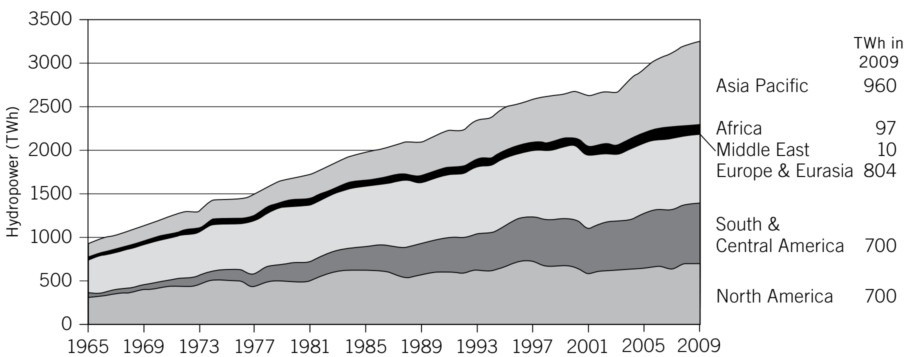
	Hydropower
Total installed capacity in 2009 (REN21, 2010)	980 GW for Hydropower (all sizes) 60 GW for Small Hydropower <10 MW
Percentage of global primary energy supply in 2008 (IPCC, 2011)	2.3
Gross electricity generation in 2008 (EIA, 2011)	3,287,554 GWh
Capacity growth 2008–2009 (IPCC, 2011)	3 per cent increase
Capacity added in 2009 with respect to 2008 (IPCC, 2011)	31 GW added

Figure 3.4. Estimated hydropower development and investment, 2000–2008



Source: Taylor (2010).

Figure 3.5. Hydropower generation by region, 1965–2009



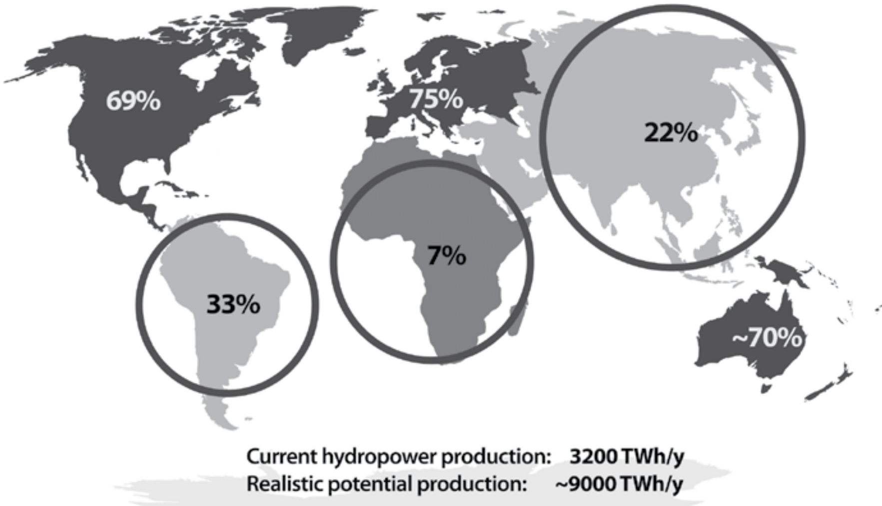
Source: BP (2010).

development now takes place (led by Brazil and China). While hydropower penetration in Africa is still low, it is also growing, with great potential for further growth.

Hydropower has the highest conversion efficiency of modern renewable energy technologies, some 96 per cent efficiency from water to wire. Given its comparatively long history, it is also has the highest penetration.[10] Hydropower's long history, high level of deployment and high conversion efficiency means that it faces skills and training challenges that are different from those faced by other renewable technology sectors.

[10] Aside from traditional use of biomass for heat and cooking.

Figure 3.6. Share of realistic hydropower potential already developed, by continent



Source: IHA (2008).

Despite the high levels of development, considerable hydropower resources remain available. The extent to which hydropower potential on each continent has already been developed is shown in figure 3.6. (For example, approximately 7 per cent of Africa's hydropower potential has been developed.)

3.5.4 Employment trends

Some estimates of occupational demand in the subsector are available from industry associations. The most recent initiative to identify/estimate occupational demand was conducted by the US National Hydropower Association (2009–2010). The study estimated full-time equivalents (direct jobs) for each part of the value chain and calculated indirect job multipliers by region. This yielded average total FTE per MW and project size for different types of technologies. The results are summarized in table 3.8.

The research estimated the employment in operations, maintenance and compliance of two to three jobs per MW in the installed base.

It was estimated that a strong renewable electricity standard could support 1,400,000 cumulative jobs in developing new hydropower capacity across the country over the period to 2025, and a weaker one up to 480,000. The

Table 3.8 US hydropower market – direct jobs to deliver hydropower projects in full time equivalents

Technology	Average Project Size	Total FTE/MW (Average)
Inland hydrokinetic	10 MW	6.00
Efficiency improvements, new capacity in existing facilities, modifications	10 MW	6.50
New facilities in low head/low flow existing dams without hydropower	10 MW	5.30
Green field (smaller)	50 MW	6.00
New facilities in higher head/higher flow existing dams without hydropower	50 MW	5.30
Green field (Larger)	100 MW	6.00
Pumped storage	500 MW (interviews) 1,000 MW (cost basis)	5.10
Ocean – Wave, Tidal	15–200 MW (literature) 50 MW (cost basis)	14.00

Source: Navigant Consulting (2009).

figure induced from the stronger scenario was divided between direct jobs (approximately 420,000), indirect jobs (approximately 280,000) and induced jobs (approximately 700,000).[11]

Hydropower assets are very long-lived in comparison to other renewables. Electro-mechanical equipment has an economic lifespan (timeframe until first major refurbishment required) of 30–40 years, and civil works 80–100 years – with most facilities having an indefinite lifespan once maintenance and refurbishment are factored in. In common with other renewables, labour intensity decreases after a hydropower project goes operational. Often the project development, construction and installation workforce can be transferred to other

[11] By "cumulative jobs" the researchers appear to mean the number of jobs in project development, manufacturing and construction and installation that will come and go over the period to 2025. From the report: "FTE/MW represents typical value (non-cumulative) required to execute a project of that size. Actual years taken to implement project will vary and this needs to be multiplied by years taken to get the cumulative man years estimate."

projects. However, where most hydropower resources have been developed, as in many developed countries, the shift in workforce profile to predominantly low level operation and maintenance activity can be more or less permanent.

The liberalization (deregulation and privatization leading to downsizing and outsourcing) of many developed country electricity markets from the early 1980s onwards, resulting in the break-up of state-owned electricity utilities and the separation of electricity generation, transmission, distribution and retail has contributed to decreasing labour intensity. Hydropower operators in developed countries are now generally involved solely in electricity generation, whereas in the past vertically integrated companies also involved in electricity distribution and other activities that covered each phase of the electricity value chain (generation, transmission, distribution and retail) were the norm. Some emerging countries are exhibiting the same characteristics as they reach maturity, and others may follow.

Due to factors noted above, the contrast between developed, emerging and least developed countries is perhaps more pronounced than for the other renewable energy sources, which are ramping up deployment in both the developed and developing world. This is illustrated in table 3.9.

Table 3.9 Country typology characteristics for hydropower

Country Type	Level of Hydropower Deployment	Growth in Hydropower Deployment	Level of Hydropower Knowhow	Hydropower Labour Intensity
Developed	high	low to moderate	high	low
Emerging	moderate to high	high	moderate to high	moderate to high
Least Developed	low	low	low	high

Source: REN Alliance background report

3.6 Geothermal

3.6.1 Background

Geothermal energy is a well established renewable energy subsector. In 2008, geothermal power production exceeded three times that of solar photovoltaics. Current growth is steady, but rather slow. While wind and solar photovoltaic are going through periods of accelerating growth, geothermal power is developing rather linearly. So far, its deployment has relied mainly on hydrothermal resources (hot rock and water) located in special geological settings.

The more universally deployable Enhanced Geothermal Systems (EGS) technology could speed up geothermal growth, although substantial research and development (R&D) efforts are needed to resolve problems (Rybach, 2010).

There are two main utilization categories: power generation and direct use. Direct use of geothermal energy means that the thermal energy from underground is used directly as heat (or cold), rather than being used to generate electricity. The range of applications includes district heating, balneology,[12] aquaculture, green houses, ground source heat pumps including space cooling, and even snow melting systems.

There are significant advantages to geothermal energy. Geothermal energy is available around the clock, independent of the time of day and night, or of the current climatic conditions. When used to generate electricity, this means that geothermal energy is base-load, suited to producing energy at a constant level, in contrast to the variable output of wind and solar power, and the peaking output of hydropower and some bio-power.

Geothermal energy's potential is ubiquitous, environmentally friendly and only marginally developed. Ninety-nine per cent of the earth's interior is hotter than 1000 °C; 99 per cent of the rest is hotter than 100°C. That said, even once EGS technologies are mature, the costs to exploit them will depend on the depth to be drilled to reach suitable hot rock resources.

3.6.2 Value chain

This value chain maps all geothermal technologies, whether direct use or power production, whether deep or shallow installations (see table 3.10).

3.6.3 Trends in sector growth

Key figures for the geothermal sector are set out in table 3.11.

The total annualized growth rate for geothermal power plants amounts to 4 per cent. In contrast to that the market of direct installations is growing significantly faster at an annual rate of 12.3 per cent (IGA). The main driver in this sector is the growing success of geothermal heat pumps (GHP). In many respects

[12] Therapeutic use of hot springs.

Table 3.10 Geothermal value chain

Equipment Manufacture and Distribution	Project Development	Construction and Installation	Operation and Maintenance	Cross-cutting/ Enabling Activities
• Design and manufacture: Drilling tools, heat pumps, pipes, collectors, other heating systems components (heat exchanger, floor heating, valves measuring and control instruments, etc.) • Auxiliary substances (grout, loop fluids, refrigerant • Quality assurance • Marketing and Sales • Delivery	• Design • Feasibility studies • Permit planning • Thermal response test • Land agreements • Selection of supplier	• Well drilling and installation bore hole heat exchanger • Services for deep geothermal drilling (mud service, casing service, directional drilling, hydraulic fracturing, logging, cementation, etc.) • Heat pump installation • Power plant installation • District heating/ cooling system installation	• Heat contracting • Power plant operation • Monitoring geothermal reservoir • Service and maintenance (pumps, pipes, etc.)	• Training • Policymaking • Management and administration • Insurance • IT • Health and Safety • Financing • Communication

Source: Authors.

Table 3.11 Key figures for the geothermal sector

	Geothermal
Total installed capacity in 2009 (REN21, 2010)	11 GW for Geothermal Power ~60 GWth for Geothermal Heating
Percentage of global primary energy supply in 2008 (IPCC, 2011)	0.1
Gross electricity generation in 2008 (EIA, 2011)	64,608 GWh
Capacity growth 2008–2009 (IPCC, 2011)	4 per cent increase
Capacity added in 2009 with respect to 2008 (IPCC, 2011)	0.4 GW added

GHP are competitive to conventional heat and cooling systems. Compared to deeper geothermal installations they do not request costly geological studies and analyses and are not dependent on the presence of thermal water.

Direct use of geothermal energy

By the end of 2009, direct geothermal applications had been installed in 78 countries, mainly in geothermal heat pumps, spas and space heating systems. An estimate of the installed thermal generation capacity in 2010 is 51 GW,[13] almost a 79 per cent increase over the World Geothermal Congress 2005 data (Lund et al., 2010), growing at a compound rate of 12.3 per cent annually. The thermal energy used in the same year is 438,071 TJ/year (121,696 GWh/yr), an increase of about 60 per cent over 2005, with compound rate of 9.9 per cent annually. This is shown in table 3.12.

Table 3.12 Summary of the various categories of direct use of geothermal energy worldwide, 1995–2010

Capacity, MWt

	2010	2005	2000	1995
Geothermal Heat Pumps	35 236	15 384	5 275	1 854
Space Heating	5 391	4 366	3 263	2 579
Greenhouse Heating	1 544	1 404	1 246	1 085
Aquaculture Pond Heating	653	616	605	1 097
Agricultural Drying	127	157	74	67
Industrial Uses	533	484	474	544
Bathing and Swimming	6 689	5 401	3 957	1 085
Cooling/Snow Melting	368	371	114	115
Others	41	86	137	238
Total	50 583	28 269	15 145	8 664

[13] REN21 estimates around 60 GWth.

Table 3.12 Summary of the various categories of direct use of geothermal energy worldwide, 1995–2010 (cont.)

Utilization, TJ/year

	2010	2005	2000	1995
Geothermal Heat Pumps	214782	87503	23275	14617
Space Heating	62984	55256	42926	38230
Greenhouse Heating	23264	20661	17864	15742
Aquaculture Pond Heating	11521	10976	11733	13493
Agricultural Drying	1662	2013	1038	1124
Industrial Uses	11746	10868	10220	10120
Bathing and Swimming	109032	83018	79546	15742
Cooling/Snow Melting	2126	2032	1063	1124
Others	956	1045	3034	2249
Total	438071	273372	190699	112441

Source: Lund et al. (2010).

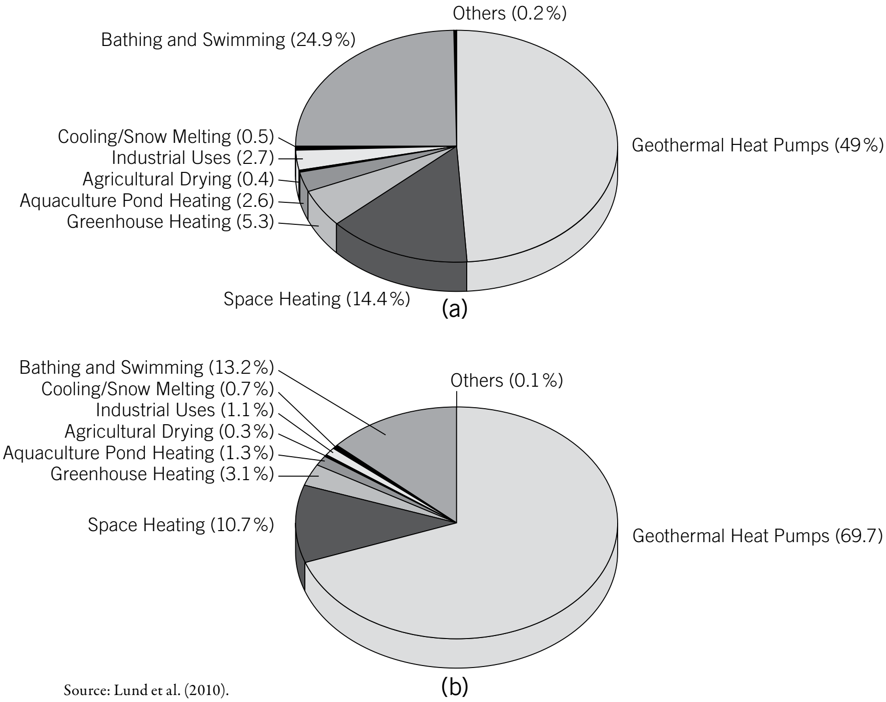
The distribution of thermal energy used by category is approximately 49.0 per cent for ground-source heat pumps, 24.9 per cent for bathing and swimming (including balneology), 14.4 per cent for space heating (of which 85 per cent is for district heating), 5.3 per cent for greenhouses and open ground heating, 2.7 per cent for industrial process heating, 2.6 per cent for aquaculture pond and raceway heating, 0.4 per cent for agricultural drying, 0.5 per cent for snow melting and cooling, and 0.2 per cent for other uses (see figures 3.7 (a) and (b))

Energy savings amounted to 307.8 million barrels (46.2 million tonnes) of equivalent oil annually, preventing 148.2 million tonnes of CO_2 being released to the atmosphere. This includes savings in geothermal heat pump cooling. Main heat pump markets are China (accounting for 24.8 per cent of the market volume), France, Sweden and Germany (Lund et al., 2010).

Geothermal power

The geothermal potential of high-temperature resources suitable for electricity generation with conventional technologies (steam turbines, binary turbines) is spread rather irregularly and depends on the volcanic zones. Potentials for enhanced geothermal systems go far beyond the potential shown in table 3.13.

Figure 3.7. Geothermal direct applications worldwide in 2010, distributed by percentage of total installed capacity (a) and percentage of total energy use (b)



Source: Lund et al. (2010).

Asia has the greatest installed power capacity. All North American capacity is located in the United States. In terms of its share of the worldwide potentials the North American resources are the most developed.

By the end of 2010, the total capacity from worldwide geothermal power plants amounted to 10,715 MW (Bertani, 2010; REN21, 2010). An increase of about 1.8 GW in the five-year period 2005–2010 has been achieved (about 20 per cent), following a roughly linear trend of approximately 0.35 GW/year. This was faster than for the preceding five years, when the increase in capacity averaged approximately 0.2 GW/year.

Geothermal power plants are in operation in 24 countries. This number is expected to increase to 35 by 2015. The main producers of geothermal energy are the United States (3.1 GW), the Philippines (1.9 GW), Indonesia (1.2 GW) and Mexico (1 GW) (Bertani, 2010).

The sector has little data available about global investments in geothermal energy R&D, technology and applications as a whole. Total annual investments in

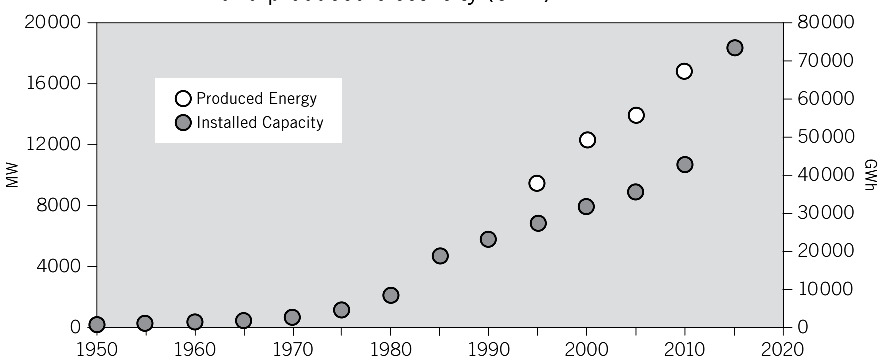
Table 3.13 Geothermal potential of high temperature resources suitable for electricity generation with conventional technologies and current installed power capacity

Region	Potential *	Current Installed Power Capacity
Asia	8 870 TWh/annum	3.8 GW
North America	4 030 TWh/annum	3.1 GW
Latin America	8 400 TWh/annum	1.5 GW
Europe	5 530 TWh/annum	1.5 GW
Oceania	3 150 TWh/annum	0.7 GW
Africa	3 620 TWh/annum	1.7 GW
World	33 600 TWh/annum	10.7 GW

* One terawatt-hour is equal to a sustained power of approximately 114 megawatts for a period of one year, depending on the type of power plant.

Source: Bertani (2010).

Figure 3.8. Installed geothermal capacity from 1950 to 2015 (MW) and produced electricity (GWh)



Source: Bertani (2010).

geothermal power plants are estimated at US$4–6 billion. According to Emerging Energy Research (EER, 2009), geothermal power plant investment could reach between US$13 billion and US$19.9 billion annually by 2020 (see figure 3.8). That means installed capacity and investment will more than triple from its current installed base from approximately 11 GW to over 31 GW by 2020.

The global cumulative installations of geothermal heat pumps are expected to grow from 2.94 million in 2010 to 5.66 million in 2015 at an estimated compound annual growth rate (CAGR) of 14 per cent for the same period

(MarketsandMarkets, 2011). That would require investments in shallow geothermal applications between US$850–950 million annually.

According to a rough estimate considering all applications together, investment in geothermal energy amounts to US$8–10 billion by now and could increase to US$21–30 billion in 2020.

3.6.4 Employment trends

In the geothermal energy sector, data about global employment is limited. Reliable data is only available from Germany and from the United States.

The German Ministry for the Environment indicates 14,500 geothermal jobs in total for 2009 (11,880 from new investment, 2,700 from operations and maintenance), up from 14,700 in 2008 and 10,300 in 2007 (BMU, 2010).

According to an employment survey conducted by the US Geothermal Energy Association (GEA) in 2004, the total number of jobs (direct, indirect and induced) supported by the existing geothermal industry was 11,460 (GEA, 2004). Based upon their 2004 analysis, GEA estimated that the geothermal industry employed about 18,000 people in 2008, from which roughly 5,000 are direct jobs in operating, construction, and manufacturing and an additional 13,000 in supporting jobs such as sales personnel, welders, machinists, educators, trainers, excavators, architects and HVAC technicians (GEA, 2009).

A 2005 study by the New Zealand Geothermal Association (NZGA, 2005) estimates that for every 50 MW (electric) geothermal generation development requires 23.5 geoscientists, 43 engineers and 17 experienced managers. This does not include the non-university trained workforce also required.

Geothermal power plants can be operated by a relatively small number of full time human resources, but require continued involvement by geothermal professionals and technicians to maintain the supply of fluid to the surface plant. Many of these people may not be employed full time on one project, but may have input into a number of projects as consultants.

Major parts of the international geothermal power industry are concentrated in companies based in the United States. Other important players include Iceland, Italy and New Zealand. Companies from the Philippines gathered in nearly 25 years of geothermal power development in their own country so much experiences in exploration and exploitation that they now seem to be ready to go abroad (Philippines Free Press, 2011).

The process of industrialization in the production of heat pumps will continue, hence, the number of people employed in manufacturing per unit will likely decrease. Rising production figures will probably compensate and stabilize employment. However, growth in the geothermal heat pump market will stimulate more demand for drilling services for heat pump installation.

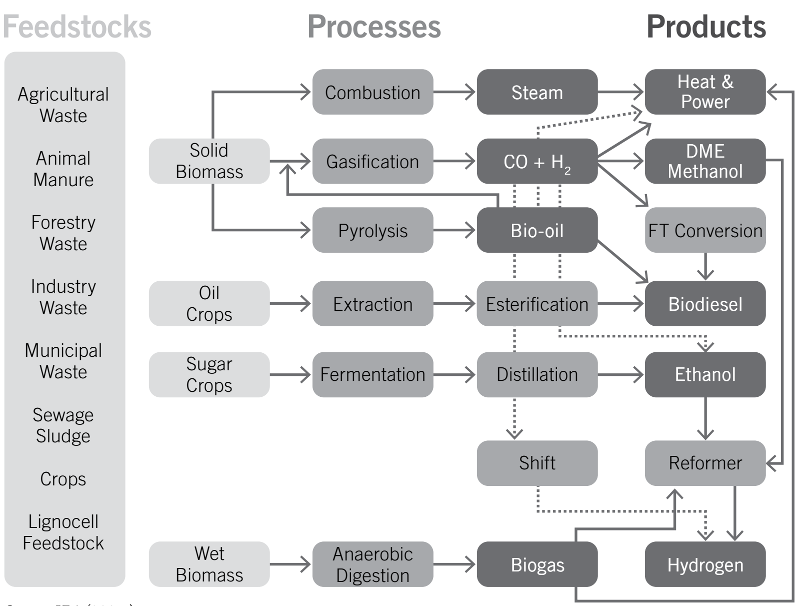
3.7 Bioenergy

3.7.1 Background

The term bioenergy refers to energy derived from any organic matter that is available on a renewable basis, including forest and mill residues, agricultural crops and associated field as well as processing residues, wood and wood waste, animal excreta, aquatic plants, fast-growing trees and herbaceous crops, municipal and industrial wastes amongst others.

Bioenergy technologies cover a broad spectrum of technologies – from primitive (for example traditional charcoal making, biomass-fired traditional/cottage industries, three-stone stoves) to advanced (for example cellulosic ethanol and biomass integrated gasification combined cycle, amongst others).

Figure 3.9. Biomass conversion paths



Source: IEA (2007a).

Biomass can be used for a wide range of products and services, including:

- Energy for heat, power and transportation;
- Food;
- Timber/construction materials; and
- A variety of other products, such as biolubricants, fibres, biosolvents, biopolymers, biocomposites, and so on.

In case of power generation, biomass-based systems can be used for both base load operation (for example direct combustion-based systems) and peak load operation (for example biogas-based systems).

At national and international level, bioenergy has often been controversial for its potential competition with food production, and because it is sometimes seen to be linked to deforestation, reducing the global availability of carbon sinks. Addressing these complex issues is outside the scope of this report, which discusses the skills and occupational needs to strengthen a sustainable production and use of bioenergy.

Energy products in the form of heat, power and fuels can be derived from biomass feedstocks by means of different conversion processes as shown in figure 3.10.

Biomass has been used as a source of energy for cooking and heating since time immemorial. Today, bioenergy demand includes both traditional and modern uses; the use of biomass in modern applications such as power generation and transportation has been rising quickly, while traditional use of biomass for cooking and other applications in developing countries has been growing at a much slower pace.

3.7.2 Value chain

Table 3.14 shows the bioenergy value chain. Different sections of the value chain have different implications for employment. Biomass production is likely to be the value chain segment with the highest employment potential, but labour intensity depends largely on the type of agriculture or forestry involved. Large-scale plantations operated with large machines employ relatively few people, while manual small-scale farming, which is typical in developing countries, is very labour intensive.

Table 3.14 Bioenergy value chain

Equipment Manufacture and Distribution	Project Development	Construction and Installation	Operation and Maintenance	Biomass Production	Cross-cutting/ Enabling Activities
• R&D • Design (digesters, refineries, components, etc.) • Quality assurance • Marketing • Sales • Delivery	• Design • Resource assessment • Environmental and social assessment • Financing • Land agreements • Permitting • Selection of supplier	• Plant construction • Pre-processing and upgrading • Processing • Quality assurance • Conversion (heat, power, or fuel)	• Operations and maintenance	• Cultivation • Harvesting • Transport	• Training • Policy-making • Management and administration • Insurance • IT • Health and safety • Financing • Communication • Biopower transmission and distribution

Source: Authors.

3.7.3 Trends in sector growth

Key figures for the bioenergy sector are set out in table 3.15.

In 2005, biomass supplied 1,149 Mtoe[14] of world's primary energy demand and was the fourth biggest source of energy after oil (4,000 Mtoe), coal (2,892 Mtoe) and gas (3,044 Mtoe). World bioenergy demand increased from 753 Mtoe in 1980 by 53 per cent during 1980–2005 (IEA, 2007b).

In line with greenhouse gas emission reduction targets to limit global temperature increase to 2° Celsius, biomass is projected to supply 2,119 Mtoe of the world's primary energy demand of 14,361 Mtoe in 2030, corresponding to an 84 per cent growth in primary bioenergy demand from 1,149 Mtoe in 2005.

World potential of bioenergy has been estimated in a number of studies. Figure 3.10 shows the potential in EJ/year in different parts of the world for four scenarios as reported by Smeets et al. (2007). The potential can be seen to be very high in some parts of the world.

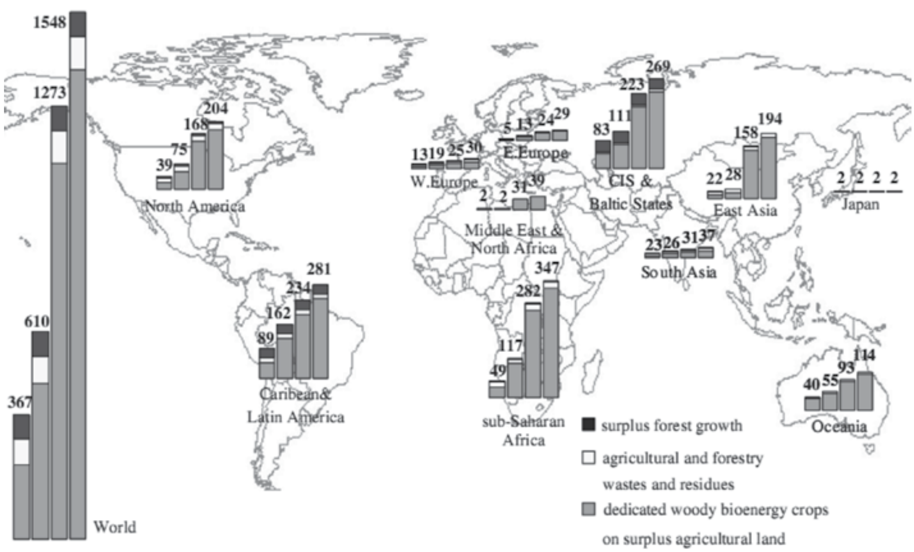
[14] Million tons of oil equivalent.

Table 3.15 Key figures for the bioenergy sector

	Bioenergy
Total installed capacity in 2009 (REN21, 2010)	54 GW for Biomass power ~270 GWth for Biomass heating 76 billion litres/year of Ethanol Production 17 billion litres/year of Biodiesel Production
Percentage of global primary energy supply in 2008 (IPCC, 2011)	10.2 per cent Biomass energy (modern biomass accounted for 38per cent of this)
Gross electricity generation in 2008 (EIA, 2011)	162,825 GWh for primary Solid Biomass 31,435 GWh for Biogas 3,443 GWh for Liquid Biofuels
Capacity growth 2008–2009 (IPCC, 2011)	Biofuels accounted for 2 per cent of global road transport fuel demand in 2008 and nearly 3 per cent in 2009*
Capacity added in 2009 with respect to 2008 (IPCC, 2011)	2–4 GW for Biopower 9 billion litres for Ethanol 5 billion litres for Biodiesel

* Data available only for biofuels

Figure 3.10. Total technical bioenergy production potential in 2050 (in EJ/year)



Source: Smeets et al. (2007).

Differences exist among countries in terms of potential of biomass. The Caribbean, Latin America, North America and sub-Saharan Africa, and the Baltic States and Commonwealth of Independent States (CIS), are known to have huge potential of biomass (Smeets et al., 2007). It is likely that large-scale plantations/biofuel production activities will start in some of these countries in the near future. In fact, production of biomass for bioenergy applications has already been started in some African countries (Songela and Maclean, 2008).

3.7.4 Employment trends

Bioenergy is employment-intensive, with jobs being created all along the bioenergy value chain, from biomass production or procurement, to transport, conversion, distribution and marketing of biofuels and electricity. It is estimated that globally there are about 1.5 million direct jobs (that is, for biomass production, harvesting and transportation, processing/upgrading of biomass, construction, operation and maintenance of conversion plants, and distribution of the final energy products) in the biofuels industry alone (REN21, 2010).[15] Indirect employment refers to jobs generated within the economy as a result of expenditures related to bioenergy fuel chain from all activities connected, but not directly related, including supporting industries and services. Spending by those employed directly and indirectly generates wider economic activity resulting in induced employment.

Bioenergy demand is expected to grow significantly in the future. According to a scenario developed by the European Renewable Energy Council (EREC) and Greenpeace, about 2.11 million jobs may exist in global biomass-based power supply alone by 2030 (EREC, 2010). The Green Jobs Report estimates potential for around 12 million jobs in biofuels-related agriculture and industry by 2030. In the United States, the biorefinery industry accounted for more than 40,000 jobs as of June 2010. The report suggested that the commercialization of second and third generation biofuels[16] was expected to create 800,000 new jobs in the United States by 2022 (Runyon, 2010). In Europe, bioenergy job potential over the next decade includes around 580,000 jobs in biomass heating, 424,000 jobs in biofuels and 2.7 million jobs in biogas (Ghani-Eneland and Chawla, 2009).

Demand for people depends on the level of deployment and the level of maturity of the technology. Modern bioenergy involves advanced technologies,

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[15] The earlier (2008) Green Jobs Report estimates “almost 1.2 million workers ... employed in generating biomass-derived energy (mostly biofuels)”.

[16] Second generation biofuels are produced from non-food crops. Third generation are produced from algae.

and several such technologies are expected to mature in the years to come. Amongst these are cellulosic ethanol, biomass IGCC (integrated gasification combined cycle), advanced automated small gasifier systems, biomass-fired Stirling engines, biochar production, torrefaction and biogas-based fuel cells.

Almost all development work on these technologies is being undertaken in industrialized countries. While energy consumption in the emerging economies has been growing rapidly, consumption of modern bioenergy in most of these countries is still generally low, with the exception of ethanol use in Brazil.

Most developing countries have yet to start deploying modern and advanced bioenergy technologies.

Section

4

Occupations in the Renewable Energy Sector

4.1 Introduction

Table 4.1 provides an overview of occupations in the renewable energy sector by subsector and value chain segment. Occupations are included under the principal stage in the value chain at which they are active.

The value chain is divided into Equipment Manufacture and Distribution, Project Development, Construction and Installation and Operation and Maintenance.

The bioenergy sector has a fifth value chain element, which is Biomass Production.

The Cross-cutting/Enabling Activities category is used to account for occupations that are important in, or affect the work of, a number of different elements in the value chain.

Clients are included as an occupational category in solar, geothermal and bioenergy subsectors as they are frequently involved in making decisions on smaller renewable installations, typically at the level of the individual building. Their skills and knowledge are required to make informed choices. This category includes people responsible for decisions on investing in renewable energy technologies such as facilities managers in businesses and householders among the wider population.

The overview of occupations in solar energy distinguishes between different types of solar energy technology: solar thermal (ST), concentrated solar (CSP), small photovoltaic and large photovoltaic. The greatest differences in occupations are in the Construction and Installation phase, where occupations are presented by type of technology.

The following coding is used to summarize the skill levels of occupations in all tables in this section:

- H = High skilled – Professional/managerial
- M = Medium skilled – Technician/skilled crafts/supervisory
- L = Low skilled – Semi-skilled and unskilled

4.2 Occupations in the wind energy sector

Equipment manufacture and distribution

Businesses operating at this point in the value chain develop, manufacture and sell wind turbines. In many cases, they are also involved in their installation. The broad types of technology involved are mechanical and electrical engineering, and also control systems. As manufacturers of wind turbines mostly produce standard models, there is not much need for turbine designs to vary between projects.

The occupations involved reflect these activities. R&D engineers from mechanical, electrical, software and other backgrounds are involved in developing turbines and their associated control systems.

The skills involved in manufacturing are broadly similar to those involved in manufacturing any heavy mechanical and electromechanical product. The skilled occupations involved include manufacturing engineers, manufacturing technicians, manufacturing operators and quality assurance specialists. Specific areas of specialism include casting and finishing mechanical parts, metal fabrication, electromechanical fabrication, assembly of electrical systems and production and installation of control systems. In many cases, production of components and subassemblies is subcontracted. Skills supporting manufacturing are also important, in areas including procurement, logistics and transport.

As businesses operating at this point in the value chain sell high value products to a wide range of customers in international markets involved in developing wind power projects, they require strong skills in marketing and sales.

Project development

A variety of types of business operate at this point in the value chain. Some act as project developers, obtaining finance, sourcing and purchasing suitable sites, obtaining permissions, negotiating contractual arrangements on power supply, contracting for the commissioning of preparatory engineering works, purchasing wind turbines, and negotiating or influencing various interests. Others provide these businesses with services.

Businesses developing wind farms vary in the extent to which they have skills in-house as opposed to contracting them in. Most make significant use of contracted in skills; many are thinly staffed and make very heavy use of contracted skills.

For this reason, businesses providing a range of types of service play a major role in wind energy. Examples include firms providing technical design services, legal services, planning advice, technical advice on wind resources and siting, assistance in obtaining consent from the electricity grid operator, services concerned with environmental assessment, obtaining consent from communities, politicians and other interests amongst others.

Many of these businesses are likely to have a range of other specialisms in addition to wind and renewable energy, which can give them flexibility to respond to changes in demand from clients without having to hire and fire staff. This also means that many people working in these areas only work on wind power part time or intermittently.

Aside from businesses involved commercially in wind projects, the wider process of gaining approval involves people working in government and regulatory roles, and indeed people working for interested non-governmental organizations, whether on a professional or voluntary basis.

The occupations involved in this stage of the value chain reflect the very diverse range of activities that must be carried out, with most of the employment being at high skilled levels, albeit with some medium skill level support staff.

Construction and installation

Businesses developing wind farm projects usually continue to take the business lead in the construction and installation phase. In most cases, they contract with construction companies and professional services firms to manage and undertake construction and installation works. In the case of offshore wind, they need to contract with construction and professional services businesses that have marine engineering capabilities. The electric grid operator will be involved in installing power lines to connect the wind farm to the grid, although the works may again be subcontracted.

Construction work includes both works on site preparation, and on installing power lines. As a consequence, the main professional level skills are in

Table 4.1 Occupations in renewable energy

	Wind	Solar (photovoltaic, ST, CSP, PS)
Equipment Manufacture and Distribution	• R&D engineers (computer, electrical, environmental, mechanical, wind power design) (H) • Software engineers (H,M) • Modellers (prototype testing) (H,M) • Industrial mechanics (M) • Manufacturing engineers (H) • Manufacturing technicians (M) • Manufacturing operators (L) • Manufacturing quality assurance experts (H,M) • Certifiers (H) • Logistics professionals (H,M) • Logistics operators (L) • Equipment transporters (L) • Procurement professionals (H,M) • Marketing specialists (H,M) • Sales personnel (H,M)	• Researchers (chemists, physicists, engineers with specialization in electrical, mechanical, chemical, materials, system design or process engineering) (H) • Chemical laboratory technicians and assistants (M) • Software engineers (H,M) • Modellers (H) • Manufacturing engineers (H) • Manufacturing technicians (H,M) • Manufacturing operators (M,L) • Building systems specialists (H) • Manufacturing quality assurance experts (H,M) • Logistics professionals (H,M) • Logistics operators (L) • Equipment transporters (L) • Procurement professionals (H,M) • Marketing specialists (M,H) • Sales personnel (M,H)
Project Development	• Project designers (engineers) (H) • Environmental impact assessment specialists (H,M) • Economic/financial/risk specialists (H) • Atmospheric scientists (H) • Social impact specialists (H) • Lawyers (feed-in contract, grid connection and financing contract, construction permit, power purchase agreement) (H) • Planners (permit monitoring, amendment and application) (H) • Land development advisor (H) • Land use negotiator (H) • Lobbyist (H)	• Project designers (engineers) (H) • Architects (H) (small projects) • Atmospheric scientists and meteorologists (H) • Resource assessment specialists and site evaluators (H) • Environmental consultant (H) • Lawyers • Debt financier representatives (H) • Developers/facilitators (H,M) • Land development advisor (H) • Land use negotiator (H) • Lobbyist (H) • Mediator (H)

Hydropower	Geothermal	Bioenergy
• Design engineers (civil, mechanical, electrical, hydropower) (H) • Modellers (H/M) • Software developers (H) • Manufacturing engineers (H) • Manufacturing technicians (M) • Manufacturing operators (L) • Quality assurance specialists (H,M) • Marketing specialists (H,M) • Sales personnel (H,M)	• Designers (H) • Electrical engineers (H) • Mechanical engineers (H) • Software developers (H) • Machinists (M) • Welder (M) • Sales personnel (H,M)	• Biochemists and microbiologists (H) • Agricultural, biological, chemical and physical scientists (H) • Chemical, biological, mechanical and electrical engineers (H) • Material scientists in R&D (H) • Software engineers (H) • Manufacturing engineers (H) • Manufacturing quality assurance specialists (H,M) • Manufacturing technicians (H,M) • Quality assurance specialists (H,M) • Logistics professionals (H,M) • Logistics operators (L) • Equipment transporters (L) • Procurement professionals (H,M) • Marketing specialist (H,M) • Sales personnel (H,M)
• Project designers (engineers) (H) • Environmental engineers (H) • Sustainability specialists (natural resource/ environmental planners, social scientists, cultural consultants) (H) • Economic/finance/risk specialists (H) • Physical and environmental scientists (hydrologists, geologists, ecologists) (H) • Market analysts (H) • Natural resource / environmental lawyers (H)	• Hydrologists, hydrogeologists (H) • Geologists (H), • Geophysicists (H) • Project designers (engineers) (H) • Permit planners (H) • Debt financier representatives (H) • Land use negotiator (H) • Lobbyist (H) • Mediator (H) • Environmental and social NGO representatives (H,M)	• Resource assessment specialists (H) • Project designers (engineers and scientists) (H) • Sustainability specialists (H) • Debt financier representatives (H) • Society and trade administrators (H,M) • Land use negotiators (H) • Communications specialists (H) • Lobbyists (H) • Mediators (H)

	Wind	Solar (photovoltaic, ST, CSP, PS)
Project Development (cont.)	• Mediator (H) • Environmental and social NGO representatives (H,M) • Public relations officers (H) • Procurement professionals (H,M) • Wind resource assessment specialist (H) • Geographers (H)	• Environmental and social NGO representatives (H,M) • Public relations officer (H) • Procurement professionals (H,M) • Resource assessment specialists (H)
Construction and Installation	• Project managers (H) • Electrical, civil and marine engineers (H) • Small wind turbine installers (M) • Construction electricians (M) • Power line technician (M) • Construction worker (M,L) • Quality control inspectors (M) • Instrumentation and control technicians (M) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)	*Solar Thermal (ST)* • System designer (H,M) • Plumbers specializing in solar (M) *Small Photovoltaic* • System designer (electrical engineers or technologists) (H,M) • Electricians specializing in solar(M) *Small Photovoltaic, Solar Thermal* • Roofers specializing in solar (M) *Large Photovoltaic* • System designers (electrical/ mechanical/structural engineers) • Installers (M) *Concentrated Solar (CSP)* • Welders (M) • Pipe fitters (M) *Small Photovoltaic, Large Photo-voltaic, ST, CSP* • Electricians specializing in solar (M) *Small Photovoltaic, Large Photo-voltaic, ST, CSP* • Project designers and managers (H)

Hydropower	Geothermal	Bioenergy
• Commercial lawyers (H) • Debt financier representatives (H) • Land development advisor (H) • Land use negotiator (H) • Communications specialists (H) • Procurement specialists (H) • Archaeologists (H) • Lobbyist (H) • Mediator (H) • Environmental and social NGO representatives (H,M) • Public relations officer (H) • Procurement professionals (H,M)	• Public relations officer (H) • Procurement professionals (H,M)	• Environmental and social NGO representatives (H,M) • Public relations officer (H) • Procurement professionals (H,M)
• Engineers (civil, mechanical, electrical) (H) • Project managers (H) • Skilled construction workers (heavy machinery operators, welders, pipe-fitters etc.) (M) • Construction labourers (L) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)	• 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) • Designers (H) • HVAC technicians (H) • Drilling technicians and operatives (roughnecks) (M) • Welders (M) • Pipe fitters (M) • Plumbers (M) • Construction equipment operator (M) • Drilling equipment operator (M)	• Biochemists and microbiologists (H) • Environmental engineers (H) • Laboratory technicians and assistants (M) • Chemical, biological, mechanical and electrical engineers (H) • Project designers and managers (H) • Software engineers (H) • Construction professionals (H) • General electricians, plumbers, roofers (M) • General construction workers (L) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)

	Wind	Solar (photovoltaic, ST, CSP, PS)
Construction and Installation (cont.)		• Project and installation evaluators (H,M) • Construction professionals (H) • Installers (M) • Software engineers (H,M) • Quality assurance specialists (H,M) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)
Operation and Maintenance	• Windsmith/millwright/ mechanical technician or fitter/ wind service mechatronics technician (M, some H) • Operations and maintenance specialists (M) • Power line technician (M) • Field electricians (M)	• Photovoltaic maintenance specialists (electricians specialiszing in solar) (M) • ST maintenance specialists (Plumbers specializing in solar) (M) • CSP maintenance specialists (M) • Inspectors (M,L) • Recycling specialists (H)
Biomass Production		
Cross-cutting/ Enabling Activities	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H,M,L) • Educators and trainers (H) • Management (H,M) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M)	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M) • IT professionals (H,M)

Hydropower	Geothermal	Bioenergy
	• Excavators (L) • Measurement and control engineers (H) • Business developers (H) • Commissioning engineer (Electrical) (H) • Transportation workers (L)	
• Engineers (civil, mechanical, electrical) (H) • Operations and maintenance technicians (M) • Physical and environmental scientists (hydrologists, ecologists) (H) • Tradespersons (M)	• Plant managers (H) • Measurement and control engineers (H) • Welders (M) • Pipe Fitters (M) • Plumbers (M) • Machinists (M) • Electricians (M) • Construction equipment operator (M) • HVAC technicians (M)	• Biochemists and microbiologists (H) • Laboratory technicians and assistants (M) • Operations and maintenance specialists (M,L)
		• Agricultural scientists (H) • Biomass production managers (H,M) • Plant breeders and foresters (H,M) • Agricultural/forestry workers (L) • Transportation workers (L)
• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M)	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M)	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M)

	Wind	Solar (photovoltaic, ST, CSP, PS)
Cross-cutting/ Enabling Activities (cont.)	• IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M)	• Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M) • Clients (H,M,L)

Source: Authors.

civil, electrical and (in the case of offshore wind) marine engineering. A variety of types of technician, electrician and construction worker are also required. Final physical installation of the wind turbine may be undertaken by the supplier, but requires broadly the same sort of skills. Commissioning the plant by finally connecting it to the grid involves electrical engineers and technicians.

Operation and maintenance

Businesses developing wind farms may manage the wind farm once it is operational, or may divest it to other investors. The main skills required from day to day are technician and skilled craft level skills in operation and maintaining the turbines, and their connection to the grid. There are also management and financial skills required, although broadly similar skills are required through all stages of the value chain, so they are included as skills under cross-cutting and enabling activities in table 4.2's summary of occupations.

Hydropower	Geothermal	Bioenergy
• Insurer representatives (H,M) • IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M)	• Insurer representatives (H,M) • IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M) • Clients (H,M,L)	• IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M) • Sales and marketing specialists (H,M) • Clients (H,M,L)

Table 4.2 Occupations in wind

	Wind
Equipment Manufacture and Distribution	• R&D engineers (computer, electrical, environmental, mechanical, wind power design) (H) • Software engineers (H,M) • Modellers (prototype testing) (H,M) • Industrial mechanics (M) • Manufacturing engineers (H) • Manufacturing technicians (M) • Manufacturing operators (L) • Manufacturing quality assurance experts (H,M) • Certifiers • Logistics professionals (H,M) • Logistics operators (L) • Equipment transporters (L) • Procurement professionals (H,M) • Marketing specialists (H,M) • Sales personnel (H,M)
Project Development	• Project designers (engineers) (H) • Environmental impact assessment specialists (H,M) • Economic/financial/risk specialists (H) • Atmospheric scientists (H) • Social impact specialists (H) • Lawyers (feed-in contract, grid connection and financing contract, construction permit, power purchase agreement) (H)

Project Development (cont.)	• Planners (permit monitoring, amendment and application) (H) • Land development advisor (H) • Land use negotiator (H) • Lobbyist (H) • Mediator (H) • Environmental and social NGO representatives (H,M) • Public relations officers (H) • Procurement professionals (H,M) • Wind resource assessment specialist (H) • Geographers (H)
Construction and Installation	• Project managers (H) • Electrical, civil and marine engineers (H) • Small wind turbine installers (M) • Construction electricians (M) • Power line technician (M) • Construction worker (M,L) • Quality control inspectors (M) • Instrumentation and control technicians (M) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)
Operation and Maintenance	• Windsmith/millwright/mechanical technician or fitter/wind service mechatronics technician (M, some H) • Operations and maintenance specialists (M) • Power line technician (M) • Wind service mechatronics (M) • Field electricians (M)
Cross-cutting/ Enabling Activities	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M) • IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M)

Source: Authors.

4.3 Occupations in the solar energy sector

Equipment manufacture and distribution

Businesses operating at this point in the value chain develop, manufacture and sell solar energy equipment. The activities involved differ depending on the technology.

- The main active components in photovoltaic technologies are made from silicon, using technologies similar to those used in making many electronic components. This stage of the work is highly capital intensive. The skills involved are similar to those required in developing and manufacturing these electronic components. They include researcher skills in chemistry, physics materials science, systems design and process engineering among others, and a range of manufacturing skills related to diffusing and processing silicon. The components are mounted into panels, which is more labour intensive. It requires a range of skills in fabricating, assembling and testing products, at levels including professional engineer, technician and manufacturing operator.

- The technologies involved in solar thermal installations are much simpler, being mostly concerned with metal or plastic fabrication and finishing. There are also electromechanical components such as pumps and electronic control equipment which may be sourced from other sectors. The main skills in design are in mechanical engineering. The main skills in manufacturing are for production engineers, technicians and skilled or semiskilled manufacturing operators.

- Concentrated solar power systems are mainly large, custom-built installations. They require design engineers specialized in areas including electromechanical systems, control systems, high temperature/high pressure vessels and steam turbines. Relying on mirrors to focus light and heat from the sun on the vessel to be heated, a substantial part of the design effort goes into designing mirrors, electromechanical systems to turn them as the position of the sun in the sky changes, and the control systems to keep them oriented correctly. Production of the components and subassemblies that will mainly be assembled on site may be undertaken at different facilities, depending on the component. In general terms, the main skills required are in production engineering, technicians, metal fabrication and finishing, assembly of mechanical and electromechanical components, electronic assembly and skills in operating a variety of types of equipment used to produce components such as mirrors.

As businesses operating at this point in the value chain sell high value innovative projects internationally, they require particularly high level skills in selling.

Project development

Solar energy projects range in size from the very small installation of a photovoltaic panel or solar thermal system in a home to the very substantial installation of a solar farm or concentrated solar power system.

In the case of a small-scale project, the project development phase may be no more than a consultation between the installer and a householder, or perhaps the installation may form part of a wider retrofitting project overseen by an architect, building services engineer (for larger buildings) or other construction professional. However, a small-scale project may form a part of a wider project to install solar panels in many buildings, and such a wider project will require at least some project development related skills that are broadly similar to those for a single large project.

In the case of a large-scale project, the entity developing the project will be involved in obtaining finance, sourcing suitable sites (whether purchasing, arranging to mount on buildings or perhaps obtaining a license to use public land), obtaining permissions, negotiating contractual arrangements on power supply, contracting for the commissioning of preparatory engineering works, purchasing solar panels and ancillary components, and negotiating or influencing various interests. They will also contract in services, which may include technical design services, legal services, planning advice, technical advice on solar resources and siting, assistance in obtaining consent from the electricity grid operator, services concerned with obtaining consent from communities, politicians and other interests amongst others.

As with wind, many of these businesses providing these services are likely to have a range of other specialisms in addition to wind and renewable energy, which can give them flexibility to respond to changes in demand from clients.

Aside from businesses involved commercially in solar projects, the wider process of gaining approval for large projects involves people working in government and regulatory roles, and people working for interested non-governmental organizations.

The occupations involved in this stage of the value chain reflect the diverse range of activities carried out. Most of the employment is at high skill levels, with some medium skill level support staff. Occupations include (among others) engineers of various disciplines for design work, professions relevant to site assessment such as meteorology, professions relevant to gaining approval such as lobbyists, mediators and land use negotiators, and the financial occupations needed to plan and obtain finance. Skills in environmental assessment may also be important.

Construction and installation

On small-scale projects, the building owner or project manager usually contracts with a business that specializes in installing the technology to do the work.

- The main skills involved in small scale solar thermal installation are plumbing-related. The work may be done by a solar thermal installer, a plumber, a "green plumber" or a heating contractor, who will often have skills in roofing (because the heat collector is most likely to be on the roof). They may work with an electrician, or a specialist installer may have sufficient electrician skills to install any necessary controls.
- The main skills involved in small-scale photovoltaic installation relate to electricity. The work may be done by a specialist photovoltaic installer, or by an electrician. Again, they will have roofing skills. Where the installation is to be integrated with grid electricity, they will need to install or link to relevant technology such as a smart meter.

On large-scale projects, businesses typically contract with construction companies, electrical contracting businesses and professional services firms to manage and undertake construction and installation works. The electric grid operator will be involved in installing power lines to connect the solar farm to the grid, although the works may again be subcontracted.

Construction work includes both works on site preparation, and on installing power lines. As a consequence, the main professional level skills are in civil, mechanical and electrical engineering. A variety of types of technician, electrician and construction worker are also required.

Commissioning the plant by connecting it to the grid involves electrical engineers and technicians.

Operation and maintenance

Small-scale installations may only undergo maintenance when a problem occurs. Large-scale installations require maintenance skills appropriate to the technology.

Much of the maintenance work in solar technologies requires skills similar to those involved in installation.

The main skills required are technician and skilled craft level skills in operating and maintaining the turbines, and their connection to the grid. There are also management and financial skills required, although broadly similar skills are required through all stages of the value chain, so they are included as skills under cross-cutting and enabling activities in table 4.3's summary of occupations.

Table 4.3 Occupations in solar

	Solar (photovoltaic, ST, CSP, PS)
Equipment Manufacture and Distribution	• Researchers (chemists, physicists, engineers with specialization in electrical, mechanical, chemical, materials, system design or process engineering) (H) • Chemical laboratory technicians and assistants (M) • Software engineers (H,M) • Modellers (H) • Manufacturing engineers (H) • Manufacturing technicians (H,M) • Manufacturing operators (M,L) • Building systems specialists (H) • Manufacturing quality assurance experts (H,M) • Logistics professionals (H,M) • Logistics operators (L) • Equipment transporters (L) • Procurement professionals (H,M) • Marketing specialists (M,H) • Sales personnel (M,H)
Project development	• Project designers (engineers) (H) • Architects (H) (small projects) • Atmospheric scientists and meteorologists (H) • Resource assessment specialists and site evaluators (H) • Environmental consultant (H) • Lawyers, government program • debt financier representatives (H) • Developers/facilitators (H,M) • Land development advisor (H) • Land use negotiator (H) • Lobbyist (H) • Mediator (H) • Environmental and social NGO representatives (H,M) • Public relations officer (H) • Procurement professionals (H,M)

Construction and Installation	*Solar Thermal (ST)* • System designer (H,M) • Plumbers specializing in solar (M) *Small Photovoltaic* • System designer (electrical engineers or technologists) (H,M) • Electricians specializing in solar(M) *Small Photovoltaic, Solar Thermal* • Roofers specializing in solar (M) *Large Photovoltaic* • System designers (electrical/ mechanical/structural engineers) • Installers (M) *Concentrated Solar (CSP)* • Welders (M) • Pipe fitters (M) *Small Photovoltaic, Large Photovoltaic, ST, CSP* • Electricians specializing in solar (M) *Small Photovoltaic, Large Photovoltaic, ST, CSP* • Project designers and managers (H) • Project and installation evaluators (H,M) • Construction professionals (H) • Installers (M) • Software engineers (H,M) • Quality assurance specialists (H,M) • Business developers (H) • Commissioning engineer (Electrical) (H) • Transportation workers (L)
Operation and Maintenance	• Photovoltaic maintenance specialists (electricians specializing in solar) (M) • ST maintenance specialists (plumbers specializing in solar) (M) • CSP and PS maintenance specialists (M) • Inspectors (M,L) • Recycling specialists (H)
Cross-cutting / Enabling Activities	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M) • IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M) • Clients (H,M,L)

Source: Authors.

4.4 Occupations in the hydropower sector

Equipment manufacture and distribution

Businesses operating at this point in the value chain are mostly involved in developing, manufacturing and selling water turbines and related electromechanical water-driven generating equipment. In many cases, they are also involved in their installation. The broad types of technology involved are mechanical and electrical engineering, and also control systems. As much of the equipment is purpose-built for specific projects, much of the work involves customizing designs.

The occupations involved reflect these activities. R&D engineers from mechanical, electrical, software and other backgrounds are involved in developing turbines and their associated control systems.

The skills involved in the manufacturing of hydropower equipment are broadly similar to those involved in manufacturing any short-run heavy mechanical and electromechanical product. The skilled occupations involved include manufacturing engineers, manufacturing technicians, manufacturing operators and quality assurance specialists. Specific areas of specialism include casting, machining and finishing mechanical parts, forming other components, metal fabrication, electromechanical fabrication, assembly of electrical systems and production and installation of control systems. Production of some components and subassemblies may be subcontracted.

Skills supporting manufacturing are also important, in areas including procurement, logistics and transport.

As businesses operating at this point in the value chain sell high value products to a wide range of customers in international markets involved in developing wind power projects, they require strong skills in marketing and sales.

Project development

Particularly with large hydropower projects, governments frequently have a deep involvement because of the physical and financial scale of these projects, their impact on the landscape and local communities, and their impact on water management and sometimes navigation. Even with a small-scale project, local government may play a prominent role. Because of this, government officials often play a major role in hydropower, particularly at the development stage.

Organizational approaches vary, with the balance between building up expertise internally within the organization charged with development, and contracting in expertise varying between projects and countries. The relatively long duration of many hydropower projects, and the fact that there is scope for decades of work on new capacity in many developing and emerging countries, means that in some contexts it may be possible to build up most of the project development skills needed within the country.

Key areas where skills are required are: civil and environmental engineering skills in design of dams and other physical infrastructure; skills in assessing the project's impact in areas including social science, hydrology, geology, ecology and environmental planning; specialists in economics, finance and risk assessment; professionals in land use; professionals in a range of areas concerned with environmental assessment and obtaining consent including lobbying, mediating and public relations and legal professionals. Representatives of environmental and social NGOs also play an important role at this stage.

Construction and installation

Most hydropower schemes involve substantial civil engineering works, requiring civil engineers, skilled construction workers and construction labourers. The mix of skills can vary depending on the location, with developing countries often using substantially more manual labour than developed countries. The installation of turbines and associated electrical mechanical and control equipment requires electrical and mechanical engineering and information technology skills, at professional and technician levels. The electric grid operator will be involved in installing power lines to connect the wind farm to the grid.

Construction work includes both works on site preparation, and on installing power lines. Commissioning the plant by finally connecting it to the grid involves electrical engineers and technicians. This stage in value chain employs by far the largest number of people.

Operation and maintenance

The main skills required from day to day are technician and skilled craft level skills in operating and maintaining the equipment, and its connection to the grid. In the case of community level off-grid schemes, there is also a need for technician and electrician skills to operate and maintain the broader network.

There are also management and financial skills required, although broadly similar skills are required through all stages of the value chain, so they are

Table 4.4 Occupations in hydropower

	Hydropower
Equipment Manufacture and Distribution	• Design engineers (civil, mechanical, electrical, hydropower) (H) • Modellers (H/M) • Software developers (H) • Manufacturing engineers (H) • Manufacturing technicians (M) • Manufacturing operators (L) • Quality assurance specialists (H, M) • Marketing specialists (H,M) • Sales personnel (H,M)
Project Development	• Project designers (engineers) (H) • Environmental engineers (H) • Sustainability specialists (natural resource/environmental planners, social scientists, cultural consultants) [H] • Economic/finance/risk specialists (H) • Physical and environmental scientists (hydrologists, geologists, ecologists) (H) • Market analysts (H) • Natural resource/environmental lawyers (H) • Commercial lawyers (H) • Debt financier representatives (H) • Land development advisor (H) • Land use negotiator (H) • Communications specialists [H] • Procurement specialists [H] • Lobbyist (H) • Mediator (H) • Archaeologists (H) • Environmental and social NGO representatives (H,M) • Public relations officer (H) • Procurement professionals (H,M)
Construction and Installation	• Engineers (civil, mechanical, electrical) (H) • Technicians (civil, mechanical, electrical) (M) • Project managers (H) • Skilled construction workers (heavy machinery operators, welders, pipe fitters etc.) (M) • Construction labourers (L) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)

Operation and Maintenance	• Engineers (civil, mechanical, electrical) (H) • Operations and maintenance technicians (M) • Physical and environmental scientists (hydrologists, ecologists) (H) • Tradespersons (M)
Cross-cutting/ Enabling Activities	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M) • IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M)

Source: Authors.

included as skills under cross-cutting and enabling activities in table 4.4's summary of occupations.

The most advanced engineering and technological knowhow remains concentrated in developed economies. Engineering services and electro-mechanical equipment manufacture are the most global of hydropower sub-industries, yet headquartered predominantly in North America and Western Europe. The actual manufacture of electro-mechanical equipment, in common with other heavy industries, has largely shifted to emerging countries. As a consequence, Brazil and China, the emerging country leaders in hydropower, are now not only leaders in deployment, but also nearing parity in knowhow. Their local hydropower developers and equipment manufacturers are becoming global players in their own right.

4.5 Occupations in the geothermal sector

Geothermal systems can be divided between deep and shallow geothermal, with shallow geothermal installations generally using heat pumps to exploit temperature differentials down to perhaps 200 m below the surface (or for some systems close to the surface), and deep ones drilling down to hot rock to generate steam and/or hot water.

Equipment manufacture and distribution

Businesses operating at this point in the chain develop and manufacture equipment such as:

- Heat pumps, which are mostly standard models that use electromechanical technologies for mainly shallow geothermal applications;
- Equipment and components such as liners to go underground in deep geothermal installations; and
- Equipment such as steam turbines and pumps to use at or close to the surface in deep geothermal systems.

The occupations involved reflect these activities. Engineers from mechanical, electrical, software and other backgrounds are involved in developing turbines and pumps and their associated control systems, and in developing other equipment and components.

The skilled occupations involved include manufacturing engineers, manufacturing technicians, manufacturing operators and quality assurance specialists. Specific areas of specialism include casting, machining and finishing mechanical parts, metal fabrication, electromechanical fabrication, assembly of electrical systems and production and installation of control systems.

Businesses operating at this point in the value chain require strong skills in marketing and sales.

Project development

The skills required in project development of deep geothermal projects centre around the geology of identifying resources that can be exploited and the design of how best to exploit each geothermal resource. Because geological conditions differ, and because the technologies involved are not yet mature, this centres on high skilled work in geology, hydrogeology, geophysics and related areas. Design of these projects is undertaken by geothermal engineers, whose original background may be in science or engineering.

There is significant overlap in deep geothermal project development skills between geothermal and oil and gas projects because of the emphasis on geology, the fact that both rely on similar drilling (and in some cases hydraulic fracturing) technologies for implementation, and because some geothermal projects reuse disused oil and gas wells.

These projects also require skills in finance, and in areas relating to environmental assessment and obtaining consent for the project, much like projects in other renewable technologies.

Project development for shallow geothermal projects is less technically demanding. Lead players may include architects or heating contractors involved in designing a heat pump system into a building development, and staff at the heat pump installation business who may have been trained by the heat pump supplier.

Larger shallow geothermal systems, serving for instance multi-dwelling building or whole settlements, need special planning skills for the geothermal system and special know-how to integrate this in the heating and cooling system in the house. Both geologists and designers dealing with the geothermal systems and the designers of building systems, especially of heating and cooling systems, have to work closely together.

Construction and installation

Drilling is central to deep geothermal installations. Some of the main occupations at this stage are associated with drilling – drilling engineers, technicians and operatives. Geothermal science and engineering continue to be important, particularly for deep geothermal, as it is necessary to respond to additional information about geological conditions obtained as drilling proceeds and as attempts are made to establish a flow of water and steam through the installation.

A range of other technical occupations are also involved in site development and constructing and installing equipment associated with handling water and steam, and installing turbines in the case of an electricity generating project. Commissioning the plant by finally connecting it to the grid involves electrical engineers and technicians.

Shallow geothermal installations are bringing together different types of trades. In most cases, these systems are based on drilled boreholes connected to heat pumps. Companies with experienced drill crews and equipment, capable of drilling holes to a depth of about 200m are required. Heating engineers, HVAC specialists, fitters, and electricians installing heat pumps also need to create the interface to the heating system.

Operation and maintenance

In large installations, the main skills required from day to day are technician and skilled craft level skills in operation and maintaining equipment including pumps and turbines, and electric grid connections. Deep geothermal installations require recurring attention from people with high level geological and geothermal engineering skills to keep them running reliably and efficiently.

There are also management and financial skills required, although broadly similar skills are required through all stages of the value chain, so they are included as skills under cross-cutting and enabling activities in table 4.5's summary of occupations.

Table 4.5 Occupations in geothermal

	Geothermal
Equipment Manufacture and Distribution	• Designers (H) • Electrical engineers (H) • Mechanical engineers (H) • Software developers (H) • Machinists (M) • Welder (M) • Sales personnel (H,M)
Project Development	• Hydrologists, hydrogeologists (H) • Geologists (H), • Geophysicists (H) • Geothermal engineers (H) • Permit planners (H) • Debt financier representatives (H) • Land use negotiator (H) • Lobbyist (H) • Mediator (H) • Environmental and social NGO representatives (H,M) • Public relations officer (H) • Procurement professionals (H,M)
Construction and Installation	• Hydrologists, hydrogeologists (H) • Geologists (H), • Geophysicists (H) • Geothermal engineers (H) • Geochemists (H) • Chemical laboratory technicians and assistants (M)

Construction and Installation (cont.)	• Drilling engineers (H) • Architects (H) • Structural engineers (H) • Surveyors (H) • Designers (H) • HVAC technicians (H) • Drilling technicians and operatives (roughnecks) (M) • Welders (M) • Pipe fitters (M) • Plumbers (M) • Construction equipment operator (M) • Drilling equipment operator (M) • Excavators (L) • Measurement and control engineers (H) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)
Operation and Maintenance	• Plant managers (H) • Measurement and control engineers (H) • Welders (M) • Pipe fitters (M) • Plumbers (M) • Machinists (M) • Electricians (M) • Construction equipment operator (M) • HVAC technicians (M)
Cross-cutting/ Enabling Activities	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M) • IT professionals (H,M) • Human resources professionals (H), • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M) • Clients (H,M,L)

Source: Authors.

4.6 Occupations in the bioenergy sector

Equipment manufacture and distribution

Businesses at this stage in the value chain are involved in the development and production of bioenergy equipment, including the development or improvement of underlying conversion processes.
The occupations that they require reflect this, being focused in three main areas:

- Science and engineering occupations required to develop equipment and processes;
- Occupations relating to manufacturing including manufacturing engineers and technicians, as well as people supporting roles such as quality assurance, procurement and logistics; and
- Marketing and sales occupations.

Project development

The success of biopower projects relies on optimizing a combination of biomass supply, technology and markets for biofuels, electricity and/or heat. There is more variation in these for biopower than for most other forms of modern renewable energy, with choices to be made between different types of biomass resource, with very different technologies available, and with market relationships that are often more complex than the standardized supply contracts offered by electricity grid operators.

Skills in resource assessment are essential, as access to an adequate supply of suitable biomass is essential. Occupations associated with environmental assessment and gaining consent for the project and for recruiting active support from potential suppliers of biomass are centrally important. Scientific and engineering skills are required to match the technology to the supply of biomass, and to develop a suitable plant design. In addition to the skills in electrical and mechanical engineering required in other renewables subsectors, skills in chemical engineering may also be required for processes such as gasification and anaerobic digestion, as may skills in biochemistry or microbiology.

The occupations involved in this stage of the value chain reflect the very diverse range of activities that must be carried out, with most of the employment being at high skilled levels, albeit with some medium skill level support staff.

Construction and installation

Construction work for biomass installations includes construction of buildings, preparation for installation of generating or other processing equipment, installing power lines to deliver electricity produced to the grid, and developing any infrastructure required to take delivery of biomass, to support outward transport of biofuels, or to provide heat to customers such as industrial users or district heating schemes. It requires a range of skills in construction, at professional, skilled construction trades and general construction worker levels.

The skills required for installation depend on the bioenergy technology involved. Construction skills and people with specialist knowledge of the equipment are required for physical installation. Skills specific to the technology are required for commissioning, which may include biosciences skills, laboratory technician skills, electrical or mechanical engineering skills or information technology and software engineering skills (including process automation) among others.

Business developers and biomass procurement specialist have important roles in establishing the supply of biomass, and in establishing markets for heat and biofuel products.

Operation and maintenance

The main skills required from day to day are technician and skilled craft level skills in operating and maintaining the equipment, whether for electricity generation, fuel production, heat production or some combination of these.

In many cases, scientific and laboratory skills are required to test biomass, to manage processes such as gasification or anaerobic digestion, and to ensure that any biofuels produced comply with specifications.

There are also management and financial skills required, although broadly similar skills are required through all stages of the value chain, so they are included as skills under cross-cutting and enabling activities in the tabulated summary of occupations.

Biomass production

Biomass production requires substantial numbers of agricultural or forestry workers to plant, manage and harvest biomass crops for as long as the bioenergy facility is in operation. Efficient production also relies on skills in agricultural science. Other important roles include biomass production managers and plant breeders and foresters. As the biomass has to be transported to be processed, significant numbers of transportation workers are required.

Bioenergy involves the cultivation and harvesting of plant biomass, processing these into a form suitable for use as fuel or as a feedstock for gas, and their distribution and utilization. Diverse skills are required throughout the multifaceted value chain. Table 4.6 summarizes the most important occupations involved in the different stages of the bioenergy value chain.

Table 4.6 Occupations in bioenergy

	Bioenergy
Equipment Manufacture and Distribution	• Biochemists and Microbiologists (H) • Agricultural, biological, chemical and physical scientists (H) • Chemical, biological, mechanical and electrical engineers (H) • Material scientists in R&D (H) • Software engineers (H) • Manufacturing engineers (H) • Manufacturing quality assurance specialists (H,M) • Manufacturing technicians (H,M) • Quality assurance specialists (H,M) • Logistics professionals (H,M) • Logistics operators (L) • Equipment transporters (L) • Procurement professionals (H,M) • Marketing specialist (H,M) • Sales personnel (H,M)
Project Development	• Resource assessment specialists (H) • Project designers (engineers and scientists) (H) • Sustainability specialists (H) • Debt financier representatives (H) • Society and trade administrators (H,M) • Land use negotiators (H) • Communications specialists (H) • Lobbyists (H) • Mediators (H) • Environmental and social NGO representatives (H,M) • Public relations officer (H) • Procurement Professionals (H,M)

Construction and Installation	• Biochemists and microbiologists (H) • Environmental engineers (H) • Laboratory technicians and assistants (M) • Chemical, biological, mechanical and electrical engineers (H) • Project designers and managers (H) • Software engineers (H) • Construction professionals (H) • General electricians, plumbers, roofers (M) • General construction workers (L) • Business developers (H) • Commissioning engineer (electrical) (H) • Transportation workers (L)
Operation and Maintenance	• Biochemists and microbiologists (H) • Laboratory technicians and assistants (M) • Operation and maintenance specialists (M,L)
Biomass Production	• 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	• Policy-makers and government office workers (H,M) • Trade association and professional society staff (H, M,L) • Educators and trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and science writers (H,M) • Insurer representatives (H,M) • IT professionals (H,M) • Human resources professionals (H) • Other financial professionals (accountants, auditors and financers) (H) • Health and safety consultants (H,M) • Sales and marketing specialists (H,M) • Clients (H,M,L)

Source: Authors.

The skills required for these occupations can be summarized according to the following categories:

- Development, planning, construction and installation related to bioenergy projects as well as assessment of environmental impacts.

- Growth and harvesting of biomass, transport and preliminary processing of biomass.
- Operation and maintenance of bioenergy plants.
- Management in areas including engineering, science, economics, social sciences, business network and others, for implementing bioenergy projects.
- Improving public knowledge and raising awareness for mobilizing support for bioenergy projects.

The occupational structure of bioenergy companies depends on the nature of their products and services. In most, managers, professionals and technicians form a sizeable fraction, if not the majority, of the workforce. In some companies, service and sales personnel also form an important fraction of the workforce. Managers and professionals usually have university degrees, often in engineering with specific on-the-job training. University degrees are also required for persons engaged in project development, report writing, financial data analysis, economic modelling, legal affairs and so on. A low to medium level of qualification is required for a number of tasks, for example office management, assembling and testing, field installation and services.

Even among industrialised countries, development of modern bioenergy technologies is far from uniform, with some countries leading in some selected technologies, for example Denmark and Sweden in biogas use for transportation, and the United States in corn ethanol. As advanced technologies spread among all countries, occupational demand will change.

Section

5

Skills Gaps and Labour Shortages

5.1 Introduction

This section starts by describing the characteristics of demand for skills in renewable energy, and how these interact with the behaviour of labour market participants and providers of education and training to create skills gaps and shortages.

It goes on to describe the skills shortages identified in the research, first looking at gaps and shortages that cut across the renewable energy subsectors, and then at gaps and shortages specific to particular subsectors.

The specific gaps and shortages found fit well with the patterns predicted by the description of the interaction between demand for skills and the behaviour of sources of skills supply.

5.2 Characteristics of renewable energy skills demand and interaction with sources of skills supply

5.2.1 Patterns of change in employment in renewable energy

Viewed globally, most parts of the renewable energy sector are still early in their development, and are undergoing rapid growth relative to the size of their existing installed base of capacity. The main exception is hydropower, which has a relatively large installed base.

Viewed at the level of national labour markets, there is more variety. In many cases technologies likely to grow rapidly in deployment in the future have not yet taken off. In a few cases, technologies growing particularly rapidly globally are relatively mature in specific countries arising from a pattern of early adoption, such as with bioethanol in Brazil and photovoltaic solar power in Germany. While hydropower is mature in most developed countries, it is undergoing rapid expansion in some emerging countries and has the potential to grow rapidly in many developing countries.

A global view on growth renewable energy subsectors, therefore, smoothes out a differentiated pattern where for each major technology there is limited activity in some countries, very rapid growth in activity in others, steady growth in capacity in some, and a relatively mature industry in some others.

5.2.2 *Implications for adequacy of skills supply*

In countries where there is limited activity, skills supply is generally not a major issue because there is not much demand. In countries where the industry is relatively mature, in most cases sources of skills supply have adjusted to meet ongoing demand.

Where growth in capacity within a country is steady, the numbers of workers needed to install new capacity remain roughly stable, but the numbers involved in operations (and biomass production in the case of bioenergy) continue to increase, driving significant demand. Once a renewable energy sector reaches this point, the supply of skills is often satisfactory because labour market participants, education/training institutions and labour market institutions have had enough time to understand the employment opportunities and respond to them effectively.

Problems with skills supply in renewable energy at country level appear to occur mainly where there are disruptive changes in demand from renewable energy sectors.

- Initially, a disruptive change in demand for skills often comes about where activity in a renewable energy sector takes off quickly, causing demand for labour to switch suddenly from a trivial level to a substantial level.
- Later, disruptive changes to demand for skills can come about where the rate at which new installations are undertaken increases or falls rapidly. A rapid increase in installation activity can cause a sudden surge in demand for skills. A rapid fall in installation activity can cause demand for new people to work in project development, construction and installation to disappear, and drive many of those already working in the area into other work or unemployment. A rapid fall in installation activity also causes demand for new people trained to operate and maintain renewable energy equipment to decrease or cease.

5.2.3 Responsiveness of training and education providers

Responding to rapid changes in demand for skills is often difficult for providers of training and education. The absolute minimum delay between recognizing a need and providing new graduates is the duration of the course, which for many relevant types of skill will be two, three, four or more years for an initial education or training course. Even for a course designed to provide specialist skills to people with a relevant existing qualification, the course duration may be anything from a few weeks to perhaps two years.

In practice, the delay can be significantly longer. Even once the decision has been made to provide a course, it takes time to design the course, to obtain any necessary approvals and funding, to assemble or develop the teaching skills required, to develop course materials and to attract students or trainees.

Many providers of training and education may be slow to decide to provide a course. Developing a course and running it for the first time requires a significant investment of time and effort that most providers will hope to recoup through running it repeatedly. If they are not reasonably certain that there will be initial and continuing demand for their graduates, even providers that are generally very responsive to employers' needs may be reluctant to make the investment.

Providers of education and training are also constrained by the expectations of prospective students and trainees. A course that is offered before activity in renewable energy takes off may not attract the "buzz" that will make it attractive. A course that fails to place its graduates because expected demand fails to appear may have difficulty in attracting more participants, and may even damage the provider's reputation.

All of this makes it difficult for providers of training and education to respond to demand for skills in renewable energy as promptly as employers in the sector, and indeed policy-makers promoting renewable energy, might prefer. The difficulties are greatest if the rate at which capacity is deployed changes quickly.

- A gradual ramp-up in activity, with visibility of growth for some years into the future, gives providers time to respond and an interest in responding. A sudden jump in activity is likely to cause skills shortages that providers cannot handle easily.

- A smooth rate of deployment, avoiding booms and busts in employment, also makes it easier for providers to respond. It will also make employment in the sector more attractive to prospective employees, and will avoid having skilled workers leave the sector for more stable employment elsewhere during a bust.

5.2.4 Differences between developed and developing countries

The skills shortages, and sometimes surpluses, that arise from disruptive changes to demand in the renewable energy sector are likely to be less severe in developed countries that already have a highly skilled population, and other sources of demand for highly skilled workers, as many of the skills required are portable across sectors.

In a developed country, a well trained construction worker, a lawyer or an electrical technician with experience in another sector will require only limited additional training to work in renewable energy, and will have good prospects of finding employment elsewhere if a shortage of renewable energy work occurs. With a much smaller pool of highly skilled workers, and with fewer alternative sources of alternative employment, disruptive changes to demand are likely to be less tractable in a developing country.

Most developing countries are less well provided with high quality providers of training and education than developed countries, making it more difficult for them to respond to skills needs through either initial or continuing training and education.

5.2.5 Renewable energy skills and existing energy industries

One possible source of specialist technical skills for the renewable energy sector is other parts of the energy sector. Oil, gas and geothermal all need drilling specialists and people with skills in geosciences and related engineering skills. All electricity-generating sectors need electrical engineers, electrical technicians, electricians and information technology specialists with broadly similar skills, and there is significant overlap between sectors in the skills they require to operate and maintain turbines of various types. Indeed, biomass is sometimes used to co-fire fossil fuel generation, and there is not very much difference between gas turbines powered by natural gas and by gasified biomass.

There will be some scope for workers in existing energy industries to move to renewable energy as the transition progresses. However, it is important not to overstate the potential. Renewable energy operations will not necessarily be located close to legacy fossil-based operations, which may be a barrier to workers otherwise interested in taking up the new jobs. Moreover, even when they are located close to each other, they are unlikely to start up and shut down at the same time, so there may be no jobs operating renewable energy installations available nearby at the time when they are needed by employees of a fossil-based operation that is winding down.

5.2.6 Planning for skills as part of planning for renewable energy

Skills availability plays an important role in facilitating the deployment and operation of renewable energy capacity. It can potentially place a hard constraint on the deployment of new capacity. It is more likely to place a soft constraint on deployment, driving up labour costs at times of high activity, and damaging labour productivity as it becomes necessary to employ people with sub-optimal skills and experience. Governments and renewable energy businesses planning the rollout of renewable energy capacity should build a skills component into their plans.

The discussion above has emphasized the positive impact that a gradual initial ramp-up of deployment of renewable energy capacity can have in terms of matching skills supply to demand. It has also emphasized the skills supply and employment benefits of smoothing the rate of deployment of new capacity over time. As the expansion of renewable energy capacity is largely driven by public policy, in many countries there will be scope for policy makers to contribute to achieving this smoothing.

There will also be scope, in many countries, for government and the renewable energy sector to improve the information about future demand for skills that is available to providers of training and education. Skills anticipation research has a significant role to play in this. Specific information about plans for future installations and the skills requirements that providers can help meet would also be valuable.

More practically, there is scope for governments and the renewable energy sector to assist providers of relevant training and education to develop their provision so that it is ready at the times when it is needed.

5.3 Principal occupations difficult to fill

Table 5.1 lists the principal occupations difficult to fill in many country contexts as identified through REN Alliance's survey among members in each sub-sector.

Table 5.1 Occupations difficult to fill

Sub-sector	Occupations
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: REN Alliance survey.

5.4 Cross-cutting skills gaps and labour shortages

5.4.1 Shortages of engineers and technicians

All renewable energy sub-sectors report skill shortages for engineers and technicians.

The general shortage of engineers in Europe and in many other countries, which arises mainly from student preferences, affects the renewable energy sector (Cedefop, 2010). Specialists in technical aspects of different renewable technologies (solar, wind, geothermal, bioenergy and hydropower) are needed, such as for example forest technicians for biomass use in France (Comité de Filière energies renouvelables, 2009). There is also a strong need for qualified design engineers (civil, mechanical, and electrical) with specific knowledge in particular renewable energy technologies.

In the wind energy sector, electrical, computer and mechanical engineers are particularly needed. The wind energy in Europe and the wind, wave and tidal power industry in the UK also face shortages of turbine technicians.

In China, the most challenging positions to fill are those of engineers and technicians. In other developing countries, such as Mongolia and Pakistan, there is a shortage of field and construction engineers.

There is a sizeable hydropower-specific engineering and technical skill gap in emerging and least developed countries. The lack of hydropower-specific engineering or technical courses available means that the sector know-how and innovation is limited to or concentrated in large developers/operators and equipment manufacturers.

Operators and manufacturers in developed countries are also experiencing difficulties in filling engineer and technician posts, arising from a general skill shortage in this area. This is leading to a high degree of competition for skilled workers between different renewable energy technologies.

There is a lack of qualified engineers in the bioenergy industry. Bioenergy engineering is still an emerging academic discipline. In a recent survey among bioenergy companies in Australia, over 85 per cent indicated that there was currently a lack of suitably skilled engineers in the industry.

There is also a general shortage of properly trained bioenergy technicians. This appears to be partly due to the fact that bioenergy uses many different sources of biomass and multiple types of process, leading to a range of types of output, including fuels, electricity, heat and chemicals. Technicians involved in biogas/landfill gas systems, production of densified products (pellets/briquettes), biodiesel and ethanol; technicians involved in bioenergy instrumentation and controls; technicians involved in biosciences laboratories – all require different types of training.

A recent study on the transition towards a low-carbon European electricity industry highlights expected changes in demand for different occupational groups in ten years' time. The results are based on the views of social partners. Demand for professionals and technicians is expected to increase most, followed by managers and service and sales workers. Most respondents believed that demand for crafts and related workers would remain stable, and that demand for plant and machine operators and low-skilled labourers would decrease (EPSU et al., 2011).

5.4.2 Skill needs for non-technical occupations

In many countries, sales specialists, inspectors, auditors, lawyers and finance-related occupations also lack the specific skills important for the development of renewable energies. Skill shortages relate to knowledge about renewable energy technologies and their social and economic benefits, environmental policies and regulations at the international, national, regional and local levels, specific measures launched by governments and other actors for financing projects and initiatives, and so on.

A specific example comes from the wind energy sectors of Mongolia and Pakistan which are affected by a shortage of finance specialists.

5.4.3 Lack of qualified trainers

A widespread shortage of qualified trainers has been identified in all renewable energy sub-sectors. In some countries, such as France, this lack is considered an impediment to the development of the renewable energy sector.

In the wind energy sector, in leading emerging countries like China, the most challenging positions to fill include trainers.

In the geothermal energy sector, in particular in developing countries like Indonesia, there may not be enough trained teachers to teach all the potential students.

A UNESCO-supported survey on *Key regional initiatives in energy education in Asia and their contribution to sustainable development in the region* (UNESCO, 2005) identified a lack of qualified teachers and supporting staff as a problem.

5.4.4 Core skills

A range of core skills are important for work in renewable energy. According to a study conducted by the Austrian Public Employment Service, environmental awareness and personal enthusiasm are highly desirable among renewable energy employees at all levels, in order to convince potential customers and to make them resilient in an environment full of counter incentives from the conventional energy interests (Heckl et al., 2008).

Managers and professionals across all sub-sectors are required to show dynamism, leadership, negotiation and strategic skills to make the most out of market opportunities when they open up for renewable energy implementation.

Due to the international nature of many renewable energy developments, especially in the area of wind, hydro and solar energy where technology is being produced and sometimes a project is managed far away from conversion sites, flexibility and willingness to travel is required for all professional areas (commercial, technical and management). Because of the international character of the sector, demand for workers with language skills, especially English, is growing.

In the wind energy sector in particular, risk analysis skills, innovation skills, interpersonal communication and negotiation skills, and marketing skills are often found to be weaker than required by employers. This applies to developed and developing countries alike.

In the hydropower sector skilled personnel at all levels tend to lack entrepreneurial, innovation, marketing, information and communications technology (ICT) and interdisciplinary skills such as systems thinking and risk analysis.

In the bioenergy sector, managers and professionals need reinforced strategic and leadership skills, entrepreneurial skills, environmental awareness, interdisciplinary skills, systems and risk analysis skills. Among skilled and semi-skilled labourers, weaknesses in environmental awareness, attitude and foreign language skills were acknowledged.

The table below illustrates the weakness of core skills among renewable energy workers in all countries consulted.

Table 5.2 Degree of weakness of core skills (high=very weak)

	Skilled/Semi-skilled Labour	Management/ Professional
Strategic and leadership skills	High	Medium
Environmental awareness and attitude/willingness to learn about sustainable development	Medium	Low
Coordination, management and business skills	Low	High
Systems and risk analysis skills	Low	High
Innovation skills	Low	Medium
Interpersonal communication and negotiation skills	Low	Medium
Marketing skills	Low	
Foreign language skills	Medium	Medium
Interdisciplinary skills	High	High
Advocacy skills	Medium	Medium

Source: REN Alliance survey.

5.4.5 Environmental awareness of clients and consumers

Demand for renewable energy is a recognized driver of the sector. Therefore environmental awareness among consumers affects their purchasing decisions. A society well informed of the environmental, social and economic benefits of renewable energies facilitates transition to a low-carbon economy by strengthening the policy and business case for the sector.

5.5 Skills gaps and labour shortages in renewable energy sub-sectors

5.5.1 Wind energy

In many countries, the sector experiences a general shortage of skills, mainly because demand is growing faster than supply. Other factors are demographic change, leakage of workforce to other sectors, less attractive working conditions in particular countries, and lack of practical skills.

Occupations commonly difficult to fill include project developers, service technicians, and data analysts. Shortages relate mostly to engineering and technical positions, but some non-technical positions are also in demand such as project managers in Europe, or finance specialists in Asia.

These skill shortages are likely to be exacerbated by fast growing labour demand, in particular in maintenance. Occupations relating to manufacturing, installation, and wind farm management will be in high demand in many countries to 2020.

The market for new installations of wind capacity shrank in many countries during the recession that started in 2008, and as a consequence some countries are not facing labour shortages in wind. This is the case, for example, in parts of Bulgaria, Canada and the United States. However, this may change as investment in wind farms increases again.

5.5.2 Solar energy

Rapid growth in solar energy applications has led to skill shortages and deficiencies in solar installation and maintenance in many countries. These have frequently caused problems (malfunctioning systems) with photovoltaic and solar thermal systems, particularly in domestic installations.

Personnel and skill shortages in installation (not in manufacturing)

According to a recent US Solar Jobs Census 2010 (Solar Foundation, 2010) the following five occupations are expected to grow the fastest over the next year:

- Photovoltaic installers (51–66 per cent growth)
- Electricians with specific experience in solar installations (42–55 per cent growth)
- Sales occupations at wholesale trade firms (40–49 per cent growth)
- Sales representatives or estimators at installation firms (39–47 per cent growth)
- Roofers with specific experience in solar installations (36–49 per cent growth)

The range of skill sets that has been identified includes electrical and construction skills and experience, customer service skills, and a baseline understanding of solar power.

High growth in particular occupations does not automatically lead to a skill shortage, but these projections indicate potential for future shortages. Employment projections for individual countries all indicate strong potential for large job creation in the coming years and decades in installations and maintenance of solar photovoltaic and solar thermal systems (UNEP, ILO et al., 2008). However, there is a growing gap between the demand for quality installations, and the skilled and qualified labour required to do the work. People working in all of the installation-related areas such as HVAC, engineering and architecture often lack the knowledge and specialized skills to understand the safety risks, good design and aesthetics associated with solar systems. At the same time, specific needs vary considerably from country to country. Installers and maintainers are particularly important in least developed countries.

In the manufacturing sector there is not such a shortage of workers. This is due in part to the fact that most of these manufacturing assembly line jobs are undertaken by general operatives, rather than by specialized workers.

Lack of skilled inspectors

In many countries, few building inspectors or others responsible for assuring building quality, have sufficient knowledge in solar installations. Many inspections have failed to identify problems in plans associated with obtaining permits. As a result, when the installation is faulty and the inspection misses the problem, the solar industry suffers from consumer dissatisfaction.

Gaps in selling, assessing sites and estimating project costs

Other areas where skill gaps have become apparent include sales, site assessment and estimation of project costs. These three functions are closely related, and involve early interaction between installation contractor and customer. Inadequate site assessment and/or project cost estimating can have serious financial consequences for the contractor, the customer or both.

5.5.3 Hydropower

Skill gaps in the hydropower sector appear in emerging and least developed countries in particular where one-off "mega" projects are commissioned, or in the former when the pace of development accelerates. This is predominantly at the operation and maintenance phase of the value chain. In developed countries, the upgrade and refurbishment of existing mature facilities is a significant and often overlooked driver, contributing to shortage in manpower.

Shortages in operating and maintaining plants in emerging and developing countries

In emerging countries, the most difficult to fill occupations are operations and maintenance engineers, technicians and tradespersons. In the earlier stages of the value chain, many emerging countries are close to being self-sufficient in manpower and skills, having undertaken significant numbers of projects already in recent years.

In least developed countries, electrical engineers, operations and maintenance engineers, technicians and tradespersons have been identified as the occupations most difficult to fill. An Africa-based survey respondent highlighted a need for trained electro-mechanics and electricians for power station and power equipment operation.

Skill shortages in assessing sustainability of projects

There are shortages of sustainability specialists (environmental scientists, cultural consultants and others) particularly in emerging and least developed countries for Clean Development Mechanism[17] projects with specific sustainability

[17] A mechanism introduced by the Kyoto Protocol to encourage project-based emissions reduction activities in developing countries. Certified emissions reductions (CERs) are generated from projects that lead to certifiable reductions in emissions that would otherwise not occur.

criteria, and for larger-scale projects that attract international attention. Apart from these specialized occupations, sustainability skills are seen as important for all those involved in the industry. The Hydropower Sustainability Protocol was introduced to set an international standard, but there is a shortage of specialists to implement it.

In developed countries, all aspects of operations require skills for a more holistic and coordinated approach to environmental matters, due to the continual ratcheting up of environmental standards (for example freshwater reforms such as the Water Framework Directive in the EU). Quality assurance skills around sustainability are also in demand.

5.5.4 Geothermal energy

Depending on sector growth rates in specific countries, engineers, planners, geoscientists and qualified workers for drilling rigs will be increasingly in demand. Currently, skill shortages arise mainly due to low demand for geothermal-specific training from students, who mostly react to short-term job trends (for example, in New Zealand and the United States).

There appears to be a shortage of science and engineering students, or at least those willing to pursue postgraduate geothermal training.

For the expanding heat pump market, specialized drillers, designers, mechanics and trained sales personnel are expected to be increasingly in demand. For larger shallow geothermal systems, careful planning is required that is often executed by highly specialized engineering offices who recruit geologists and geophysicists and designers of technical building systems. For fitting companies a growing geothermal heat pump market means there is a need to bridge a skills gap that arises from conventional to new heating and cooling systems. Architects, designers and installers need to be sensitized to help increase adoption.

5.5.5 Bioenergy

Since large-scale interest in bioenergy is a relatively new development in most countries, skill shortages exist in practically all core occupations. Training provision has not yet caught up with demand for skills.

The following occupations are likely to be most in demand over the next five years according to the REN Alliance survey: scientists/engineers, service technicians, project managers and corporate advisors. A study carried out in California found that the majority of employers faced difficulty hiring for all seven occupations[18] identified in the study (COE, 2011).

A study of IEA Bioenergy Task 30 for identifying barriers to the full-scale implementation of short rotation crops for energy production in IEA member countries found that the lack of availability of suitable staff with the appropriate skills required to install and manage large-scale bioenergy demonstrations was a barrier to the adoption of short rotation crops (SRC). Similar barriers are expected to exist in other bioenergy sectors.

In a survey among bioenergy companies carried out in Australia (Clean Energy Council, 2009):

- Over 70 per cent reported skills gaps in their industry, with power engineers being particularly short in supply;
- Seventy per cent of bioenergy companies reported difficulty finding suitably trained staff to carry out renewable energy-related work; and
- Respondents deplored a general lack of understanding of potential for renewable energy in the Australian market, and non-availability of tertiary training in this field.

The Australian experience is probably representative of many countries in the initial phases of implementing bioenergy programmes. Countries which have not yet started SRC plantations will no doubt face this problem in the future. This may be particularly true for developing countries in Africa and Latin America that have significant energy plantation potential.

The nature and extent of skill gaps and shortages vary depending on countries and regions. There is no significant shortage in developed countries that have developed strong bioenergy programmes (for example Denmark and Sweden). Shortages exist in countries in the early stages of implementing such programmes. For example in Ireland, a report in 2005 noted nine key gaps in bioenergy skill provision within the education and training system cutting across a wide range of occupations (Healion et al., 2005).

Least developed countries, which depend heavily on traditional biomass, need to use their biomass resources more efficiently, and start more extensive use of modern bioenergy. Most lack researchers and skills across all occupations relevant to bioenergy.

[18] Bio-energy Manager/Supervisor; Biomass Plant Technicians; Bio-energy Engineering Technician; Bio-energy Instrument and Controls Technician/Operator; Methane/Landfill Gas Collection System Operators/Technicians; Bio-energy Research Assistant/Analyst; Biofuels Processing Technician

Section 6
Skills Response

6.1 Introduction

This section describes and analyses the measures taken to meet the renewable energy sector's skills needs.

Existing initial education and training courses and apprenticeships go a long way towards meeting this sector's skills needs.

- Most countries with significant activity in producing renewable energy equipment also have substantial activity in manufacturing other engineering products, and have well established systems to develop the skills that these enterprises need. While there may be problems with skills supply (such as a general shortage of engineers and engineering technicians in some countries), the fact that these affect renewable energy does not give rise either to new problems or to new solutions.
- The basic occupational skills required for many jobs in renewable energy project development, construction and installation, and operations and maintenance are already delivered through existing programmes of education and training. Existing university courses in electrical, civil, mechanical and environmental engineering, biosciences, geosciences, agriculture and forestry, law, business, information technology, the social sciences, architecture and a range of other disciplines provide the necessary foundation for professional level work in renewable energy. Technician and skilled craft level courses and apprenticeships in technical disciplines including electrical, mechanical and civil engineering, biosciences and a wide range of skilled construction

occupations provide a good basis for working at technician level in renewable energy industries.

However, even with the basic skills requirements of most jobs in renewable energy being covered by existing courses, those who have these skills also require more specialized skills in the area, and in some cases benefit from skill sets that cross existing occupations.

Most of the skills response to the needs of the renewable energy sector is about delivering these specialized and cross-disciplinary skills, either through providing initial education and training courses and apprenticeships specialized in renewable energy, or through providing supplementary education and training in renewable energy to build on existing skills.

Supplementary education and training may be targeted on:

- New graduates of less specialized courses designed to prepare them to work in renewable energy;
- People with relevant skills from other sectors, to provide them with the specialist skills and knowledge that they require to work in renewable energy; or
- People already working in renewable energy, to fill gaps in their skills or to upskill them.

In some cases, training courses relevant to renewable energy are targeted on people who are unemployed, both as a means of supplying needed skills and as an active labour market measure to assist them in returning to the labour market.

In addition to responses based primarily on training, some responses to skills shortages and gaps rely on sourcing skills for renewable energy from elsewhere – from other countries or from other sectors within the same country. Sourcing from other countries can be in the form of recruiting or contracting with individuals, or it can be in the form of contracting with an overseas service provider to do work in areas such as project development or technical and project management of the construction and installation stage.

6.2 Specialist technician and skilled crafts courses

Initial education and training courses aimed at technician and skilled crafts level are an important feature of the response to skill needs in the wind, solar, hydropower, geothermal and bioenergy sectors internationally.

Important sources of training at this level include:

- TVET colleges:
- Apprenticeships;
- Suppliers of renewable energy technologies.

While many apprenticeships are formal and coherent with the mainstream apprenticeship system in the country concerned, some are run within large enterprises. For example, it is common for businesses in hydropower – both operators and specialist contractors – to train their technician level employees through apprenticeship systems. One example is the apprenticeship system run the Northwest Public Power Association (NWPPA) in the United States.

One of the main specialist skills requirements of the wind, hydropower and bioenergy sectors at the operations and maintenance stage of the value chain is for technicians and skilled crafts workers to operate and maintain the renewable energy equipment. In the solar sector there is a similar need for operations and maintenance people in concentrated solar power and in larger photovoltaic and solar heat installations.

There is an intermittent need for people to repair smaller-scale photovoltaic and solar heat installations. In areas where these are installed in large numbers there is potential for significant employment in providing maintenance services.

This work requires a combination of the basic technological skills and knowledge associated with more general technician qualifications and specialist skills and knowledge associated with the specific type of technology involved. For example, while a person with a general mechatronic technician qualification would be well equipped to learn to operate and maintain the wind turbines, power cabling and control systems of a wind farm, they would need significant further specialized training to do so.

One of the most common types of response to this need is the creation and provision of initial education and training courses, and sometimes apprenticeships, to develop technician and skilled crafts skills in these areas. Some of this demand is also satisfied through additional training for people who have relevant technology skills, but need more specialist training.

The major types of course or apprenticeship provided include:

- Wind power technician;
- Hydropower technician;
- Bioenergy technicians, usually with a specialism in a particular type of bioenergy technology.

In solar, aside from concentrated solar power, the main focus of most technician and skilled crafts level courses is on installation (see below), but much the same skills are required for operations and maintenance.
Examples of courses include:

- A new course in Installation and Maintenance of Wind Farms offered by vocational training colleges in Spain;
- Training for youth and women as certified solar technicians and repair and maintenance specialists in Bangladesh to complement a programme of micro-loans to install home solar systems by Grameen Shakti;
- A joint initiative by the Los Angeles division of the National Electrical Contractors Association (NECA) and International Electrical Workers Union (IBEW) to develop a three-day photovoltaic installation course for union members;
- Six-month bioenergy training courses offered by INNET/TU in China;
- Upper secondary vocational education as a renewable energy technician specialized in solar systems offered by Instituto de Educação Técnica – INETE in Lisbon, Portugal;
- Specialized training for HVAC technicians recruited into the bioenergy sector in Washington State in the US, using a variety of training approaches;
- Training for rural technicians to assist agricultural producers in Brazil in integrating energy crops into their agricultural systems under the National Biodiesel Programme; and
- A two year training course as a geothermal technician managed by a provincial agency in collaboration with employers and unions in British Colombia in Canada.

The US Department of Energy is endeavouring to improve the quality of training in solar installation through the Solar Instructor Training Network, a train-the-trainer initiative.
Ideally, these courses strike a balance between three objectives.

- Providing a good education that will continue to be useful once current technologies are long obsolete;
- Developing the essential skills and knowledge required to work with current technology from all competing technology suppliers; and
- Developing the detailed skills and knowledge required to work with technology from one or more specific suppliers.

Training for operations and maintenance often takes place in a context where the specific technologies installed, or to be installed, in local operations are known.

There is also a need for people with technician and skilled crafts skills at earlier stages (project development and construction and installation) in the value chain. However, much of the requirement is for skills that are not specific to renewable energy – such as general construction trades and civil engineering and architectural technicians. The need for additional specialist training is limited, and to the extent that it is necessary it can mostly be provided or sourced by employers.

In some renewable energy subsectors, much of the more specialized employment in installation is associated directly with manufacturers and distributors/agents for technologies, who contribute to installing the technology themselves, reducing the need for project developers to source specialist skills themselves.

It is mostly for small-scale installations that there is a need for technician level skills in installation to be developed independently of manufacturers and distributors. The most significant areas are in solar – both photovoltaic and solar heat – where a large share of all installations are small-scale – most often at the level of an individual building. For this reason, courses in photovoltaic installation and solar thermal installation are needed wherever widespread deployment of these technologies is planned or underway. Depending on the country context, these courses may be mainly either substantial initial training qualifications or much shorter courses designed to provide existing electricians, plumbers and sometimes roofers with the additional skills required to install these technologies.

The skills development requirement is more complex for installation work on mid-sized projects, such as renewable energy installations for large buildings.

- For some projects around this size, installation work may be provided by the supplier (manufacturer or distributor) of the technology. In these cases, the supplier will usually have provided technicians and skilled crafts workers with any specialized training required.
- In other cases, the installation work may be provided by an independent engineering services business, often because installation of the technology forms just part of the wider project. Many businesses operating in this part of the market are finding it challenging to keep up with increasing technological complexity. They may not have access to training from the supplier of the technology, and even if they do the investment of time and money required may be disproportionate to their market opportunity. This is an issue that needs to be resolved, as skills deficiencies expose clients to the risk that equipment will be installed improperly, and will not perform as designed.

There is no single solution. The barriers to training in proprietary technologies arise as much from competing interests between suppliers and installers, and conflicting incentives seen both by suppliers and installers, as from innovation and increased technological complexity. To a great extent these issues have to be resolved by the businesses concerned. Where suppliers of renewable energy technologies have a clear-cut interest in training operations, and maintenance technicians and skilled crafts workers in their technology, they may have less interest in training people who may compete with their own installation service, or reduce their control over their distribution channels.

6.3 Specialist university courses

There is less need for specialist initial education courses in renewable energy at the university level than at the technician and skilled crafts level. As noted earlier, existing university courses in electrical, civil, mechanical and environmental engineering, biosciences, geosciences, agriculture and forestry, law, business, information technology, the social sciences, architecture and a range of other disciplines provide the necessary foundation for professional level work in renewable energy.

Even so, many universities are shaping some of their initial education course offerings to better meet the needs of the renewable energy sector – in some cases they are remoulding existing content or adding renewable energy options without changing the course title; in other cases, they are creating new courses in renewable energy. The study identified examples of this being done with university courses in engineering, biosciences and business.

Some examples include:

- Renewable Energy Engineering (bachelor degree) at Oregon Institute of Technology, USA;
- Mechanical and Energy Engineering BSc at Reykjavik University, Iceland;
- Environmental Engineering – Renewable Energy Sources at Krakow University, Poland; and
- Mechanical Engineering with Major in Energy Conversion at University of Miskolc, Hungary.

In addition to, or as an alternative to, initial education courses in renewable energy, many universities are offering postgraduate courses designed to provide graduates with more general qualifications with the specialist skills that they need to undertake high level professional work in renewable energy. For example, the University of Auckland in New Zealand offers a postgraduate diploma in Geothermal Energy Technology, as well as relevant masters and PhD programmes. The Faculty of Technology at the Makerere University offers a masters degree programme in Renewable Energy.

6.4 Continuing education and training

Continuing education and training has an important role in renewable energy. Providers are diverse, including renewable energy businesses themselves, industry associations, trade unions, suppliers of renewable energy technologies, universities, colleges and private training providers among others.

Continuing education and training is important at all levels, and both in technical and non-technical occupations.

In technical occupations, it is required to keep skills and knowledge up to date as technologies change, to prepare people with relevant skills from other sectors to work in renewable energy, to develop cross-disciplinary skills and knowledge, and to improve core skills in areas including problem solving, communication and teamworking.

In non-technical areas, there is a particular need to develop industry knowledge, and keep it up to date. A wide array of industry, regulatory and business organization issues that are specific to the sector can be important. In addition, renewable energy is a technology sector, there is a need for non-technologists to have at least a basic understanding of technology issues, and a very good understanding of their business, regulatory and legal implications.

6.5 International linkages in renewable energy qualifications

Because renewable energy technologies, and to a great extent skills requirements, are similar across different countries, there is significant scope to standardize skills and qualifications requirements across countries globally. There are limits to this: some skills are country-specific, reflecting different legal and regulatory conditions; and to varying extents there are technical differences in construction and infrastructure between countries. Also, while the skills required to implement a technology may be identical across different countries, the actual mix of skills needed varies depending on the mix of technologies implemented, which varies with resource conditions, government policies and other factors.

However, the overall picture is that skills requirements for a renewable energy technology, particularly technical skills requirements, are fairly uniform internationally.

This uniformity makes it meaningful to establish international linkages between qualifications in renewable energy.
Doing so has some valuable consequences.

- International linkages between qualifications make it possible for employers to understand the content, level and quality of a qualification from an institution or a country that they do not know well. This facilitates international mobility among workers in a sector in which mobility is beneficial both to employers and workers. It also facilitates a renewable energy business in assessing the skills of workers available locally if it contracts to undertake a project, or undertakes an investment, in a country that it does not already know well.

- It is a good way to spread good practice in provision of education and training internationally. It facilitates institutions that are already expert in providing education and training in renewable energy in learning from their peers. It gives institutions that are new to renewable energy access to high quality, industry-recognized course designs and course content, along with the advice they need. This allows them to get high quality courses running faster and with less investment in course development than would otherwise be required, making it easier to respond efficiently and without unnecessary delay to skills demand.

Examples of international linkages in renewable energy qualifications include the following:

- The Windskill initiative, funded by Intelligent Energy Europe is a transnational training strategy for the European wind market. It developed common occupational profiles for a number of occupations in wind, and piloted courses linked to these profiles.

- Desertec University brings together 18 universities and research facilities from the Middle East and North Africa to provide education and training in solar power. This complements the Desertec Foundation's plans to develop solar power generation on a large scale across the region.

- The Institute for Sustainable Power (ISP) is a non-profit organization which coordinates, develops and maintains international standards for qualifications and training of renewable energy, energy efficiency and distributed generation providers. Organizations accredited by the ISPQ Regional Licensees, and individuals certified, attest that they have the skills and resources to deliver high-quality training covering the skills and competency requirements of specific renewable energy, energy efficiency and distributed generation trades.

- The North American Board of Certified Energy Practitioners (NABCEP) is another example of initiative in this sense. It is a panel of solar industry experts that offers training as a part of its voluntary certification programme. Courses are offered through many institutions in the entire country.
- A global network of universities and centres of excellence in geothermal research and also industrial partners is being created around the International Geothermal Centre of Excellence (IGZB) in Bochum, Germany. The Chilean partner, for example, is the Andean Geothermal Centre of Excellence (CEGA), a confederation of the five most important universities of Chile. In New Zealand, the partner of the network is the Institute of Earth Sciences and Engineering (IESE) of the University of Auckland, specialized in seismic technologies.
- In the hydropower sector, agreements have been established between Argentina, Brazil and Paraguay, and between Brazil and Germany for training engineers and technicians.

REN Alliance, the alliance of world renewable energy industry associations, which undertook much of the background research for this report, has identified common standards for skills and qualifications in renewable energy as offering an opportunity to make progress towards achieving high and uniform standards in training and education for the renewable energy sector internationally.

Section 7

Anticipation of Skills Needs

7.1 Introduction

In a rapidly evolving sector such as the renewable energy sectors, where skill shortages are apparent, anticipating skills needs is an important policy issue. In order to make informed policy decisions, governments and social partners are raising questions including: What are the skill needs for the development of the sector? What are the training needs to ensure effective implementation of policies? Which occupations will be affected? How many people will need to be trained? Which training and education institutions should be involved?

This chapter looks at methods and approaches to employment projections at the global level and in different sub-sectors of renewable energy. Quantitative methods for estimating employment potential are not enough to forecast skills needs. They need to be coupled with qualitative methods such as company surveys, interviews, case studies or focus groups discussions, to provide results that are meaningful from a skills policy perspective. Examples of combinations of quantitative and qualitative models, and examples of purely qualitative approaches used to identify skill needs in countries are explained.

The chapter finishes with a discussion on the importance of social dialogue and the involvement of workers and employers in the process of identification and anticipation of skill needs.

7.2 Sectoral scope of anticipation

7.2.1 Introduction

Early in every anticipation project addressing renewable energy it is necessary to consider what the sectoral scope will be.
There are two major aspects to sectoral scope.

- Which sectors (and part sectors) are of interest to the research?
- Which sectors (and part sectors) will be addressed primarily through sector level research, and which will be addressed primarily through using some form of macroeconomic modelling, such as, for example, input–output analysis or a computable general equilibrium model.

It is possible for a renewable energy anticipation project to consider employment impacts across the whole economy, with sector level research being used to address selected sectors, and a macroeconomic approach being adopted to model the impact of anticipated sector level developments throughout the rest of the economy. It is also possible to take a narrower approach.

There is no single correct solution to the scope question – it depends on issues that include, among others, the research question, the country context, data availability and project resources.

7.2.2 Types of sector

There are a number of types of sector to be considered when deciding on the sectoral scope of an anticipation project on renewable energy.

Core renewable energy sectors

Core types of business that almost every renewable energy skills anticipation project will address are:

- Sectors whose primary activity is producing and/or distributing renewable energy, whether in the form of electricity, fuel or heat; and
- Sectors producing renewable energy systems and technologies.

Extended renewable energy sectors

Most renewable energy skills anticipation projects also look at other sectors where significant employment associated with renewable energy occurs. These are encompassed in the renewable energy sector as addressed by this report.
Key sectors include:

- Construction;
- Professional services;
- Agriculture and forestry.

The line between businesses in these sectors that are associated with renewable energy and those not associated with renewable energy may be quite fuzzy. A construction business, for example, may have clients across a range of sectors that includes renewable energy, and may vary its activity in renewable energy depending on current demand from clients.

Other energy sectors

In many cases, skills anticipation research in renewable energy addresses both renewable energy sectors and other energy sectors, including among others:

- Sectors focused on extracting, processing and distributing fossil fuels;
- Electricity generation and heat production from fossil fuels;
- Nuclear energy, including electricity generation and extracting, processing and eventual storage of nuclear fuels.

There are three main reasons why this is done in a project whose main topic is renewable energy:

- Projections of demand for energy from renewable sources play an important role in projecting employment in renewable energy industries, and this subset of energy demand is affected by supply from non-renewable sources.
- The transition to renewable energy does not just impact on demand for skills in the renewable energy sector, but also on demand for skills in the non-renewable sector. Many research questions are interested in employment and skills effects in the wider sector, and not just in renewable energy. It is likely that in many cases employment will be lost in non-renewable sectors, and understanding how this is likely to proceed is important for a range of policy reasons, not least planning for a Just Transition from fossil-based to renewable energy.

- The supply of skills available to the renewable energy sector is affected by developments in non-renewables. Many technical skills, such as in electrical engineering, turbine technician skills and drilling skills, can be applied in either sector. The non-renewable energy sector may compete with the renewable sector for skills, may be a reservoir from which the renewable sector can draw skills, or may provide a complementary source of demand for skills that assures people choosing initial education and training courses relevant to renewable energy that there will be demand for their skills.

Energy-intensive sectors

When anticipating future demand for skills in the energy sector within a country, some researchers choose to undertake sector level research into sectors that are particularly important users of energy within the economy. Developments in demand for energy from these sectors will impact on future demand for energy, which will in turn impact on employment in energy sectors.

Research in this area may focus on the likely impact of measures to promote the transition to the low-carbon economy on these sectors, such as carbon pricing or environmental legislation, or may project energy demand based on a broader and more holistic view on each sector's prospects.

Some energy-intensive sectors undertake energy producing activities themselves. This can be renewable (for example, using wood waste to fire a combined heat and power plant at a particle board mill) or non-renewable (for example, coal-fired electricity generation to power the refining of alumina into aluminium). In countries where this accounts for a significant share of energy output, it may be necessary for a skills anticipation project on renewable energy to take account of this activity.

Small-scale renewable energy installations

Production of renewable energy does not just take place in the renewable energy sector and in some energy-intensive businesses. It also takes place in a wide range of commercial, industrial and residential settings, often at the level of a building, and sometimes at the community level (such as with a biomass-fired community-level combined heat and power scheme).

While community level activity may fall within a statistical definition of the renewable energy sector, smaller-scale activity may not be recorded. This may not be a major issue where building scale renewable energy activity is low. It is a significant issue where activity is high or expected to grow quickly as in the case of solar thermal and photovoltaic installations in many countries, and in the case of geothermal heat pumps and modern biomass-fired heating and cooking systems in some countries. Installing and maintaining these technologies has significant skills requirements.

Other supply chain sectors

While much of the employment associated directly and indirectly with renewable energy is encompassed by the sectors already described, there is also significant employment in sectors supplying these renewable energy sectors with services and goods not specifically associated with renewable energy, such as auditing and stationery. Employment of this sort can be estimated using input–output analysis.

Some research questions take an interest in the skills profile of indirect employment, including employment in these sectors, but generally only at a very high level, distinguishing between perhaps three levels of skill.

Induced employment

Some research questions are interested in employment in the wider economy that arises from spending by employees of renewable energy businesses and their suppliers, or induced employment. This can be estimated using various macroeconomic methods.

Complexities arise in estimating induced employment where: employment gains in renewable energy are offset by loss of employment in other energy sectors that offsets part of the increase in consumer spending; labour supply imposes a constraint on the extent to which increased consumer spending can generate employment; investment in renewable energy may displace other forms of investment; and measures taken to promote renewable energy have the potential to impact (whether positively or negatively) on activity elsewhere in the economy.

Some research questions take an interest in the skills profile of induced employment, but again generally only at a very high level.

7.2.3 Choosing how to address each type of sector

Once the sectors of interest to the research have been chosen, it is necessary to choose how to approach researching each sector.

The first choice to make is between an approach that emphasizes quantitative research, an approach that is primarily qualitative in nature, and an approach that integrates quantitative and qualitative research and analysis.

Having made this choice, the next choice is which sectors will be addressed primarily through sector level analysis, and which primarily through a more macro approach. Qualitative analysis will almost always be undertaken through sector level research.

For quantitative analysis, some sectors can be addressed primarily with data available from standard statistical sources, but it is necessary to address at least some sectors with sector level research, in the form of a sectoral study based on primary research into the sector.

Sector level research will almost always cover the core renewable energy sectors. In many cases, there will be very limited statistical information available on these sectors, and it will be necessary to undertake survey and case study research, or to undertake new analysis on primary data sources, to provide the statistical information required for quantitative aspects of skills anticipation. Even where there is useful statistical information available (for example, from statistics on environmental goods and services), it is likely to be necessary to supplement this with original research to bridge gaps in the data available, such as perhaps the absence of sector occupational profiles.

In addition to quantitative research into the sector, qualitative research is also required to develop realistic scenarios, and as an input into projecting demand for energy from the sector.

Research into the extended renewable energy sectors can be undertaken at the sector level, using a macroeconomic approach, or using a combination of both approaches. At the sector level, case study or survey research can be used to identify the employment, occupations and skills in construction, professional services and agriculture/forestry associated with project development, construction and installation, operations and maintenance and (in the case of bioenergy) biomass production associated with the installation and operation of each unit of capacity and output. A macroeconomic approach uses input–output tables (from national accounts) to estimate the relationship between activity in core renewable energy and extended renewable energy sectors. Where sufficient resources are available, a combination of both approaches may be preferable, using the macroeconomic approach as a check on the sector level approach, and using evidence from sector level research to improve input–output data for sectors that include both renewable and non-renewable energy businesses.

Research into other energy sectors can also be undertaken at the sector level, using a macroeconomic approach, or using a combination of both approaches.

If there is a serious interest in anticipating employment and skills requirements in these sectors, it will usually be addressed with sector level research, with the results often being integrated into a macroeconomic analysis that will include a representation of energy prices.

The purpose in analysing energy-intensive sectors separately from other sectors in the context of a study on renewable energy is to be able to better model demand for energy. This requires sector level research. The results of this research may be integrated into a macroeconomic analysis that may include a representation of energy prices.

Research into skills for small-scale renewable energy installations has to be undertaken at the sector level, as most employment will be in a niche within the construction sector that will not be addressed separately by standard statistical sources.

The main purpose in analysing other supply chain sectors is to contribute to estimates of total indirect employment (or total direct plus indirect employment). This will be modelled using some form of macroeconomic analysis that will include an input–output analysis.

Analysis of induced employment is usually undertaken using some form of macroeconomic analysis.

7.3 Segregating renewable energy from non-renewable energy activity inquantitative analysis

Sector level research forms an important part of most skills anticipation research in renewable energy. Where conducted at country level, it almost invariably combines quantitative and qualitative approaches.

Renewable energy skills anticipation research cuts across standard sectoral classifications in most contexts. Large parts of renewable energy's skills requirements appear in each of the following ISIC classifications:

- 01 – Crop and animal production, hunting and related service activities
- 02 – Forestry and logging
- 09 – Mining support service activities
- 25 – Manufacture of fabricated metal products, except machinery and equipment
- 27 – Manufacture of electrical equipment
- 28 – Manufacture of machinery and equipment n.e.c.

- 33 – Repair and installation of machinery and equipment
- 35 – Electricity, gas, steam and air conditioning supply
- 41 – Building construction
- 42 – Civil engineering
- 43 – Specialized construction activities
- 71 – Architectural and engineering activities; technical testing and analysis

Data sources important for skills anticipation for which data are generally organized by standard sectoral classifications include:

- Data on employment, in total and by occupation from Labour Force Surveys;
- Data on business activity from official enterprise surveys and/or administrative sources; and
- Input–output and similar tables showing how activity in each sector impacts on other sectors.

For each standard industry classification, renewable energy accounts for only a part of the classification. Quantitative analysis of renewable energy skills needs therefore cannot depend only on standard sector statistics in most countries. It is necessary to find a way to segregate renewable energy activity from other activity within each of these sectors, developing a set of synthetic renewable energy sectors.

In some country contexts, it is possible to go a long way towards doing this by using other standard statistical sources.

- In some countries, for example, good progress has been made in developing statistics on environmental goods and services that provide useful data on renewable energy.
- Some other countries have more detailed classification systems that allow useful information to be extracted. For example, the North American Industry Classification Systems distinguishes between Fossil Fuel Electric Power Generation (221112), Nuclear Electric Power Generation (221113), Hydroelectric Power Generation (221111), Other Electric Power Generation (221119 – almost all renewable) and Solid Waste Combustors and Incinerators (562213 – includes waste to energy).
- Data from a range of other types of official and semi-official statistical source can also be helpful in characterizing parts of the renewable energy sector. Significant sources include trade statistics, statistics on energy, production statistics and statistics on agriculture and construction among others. Official

bodies such as energy regulators, agencies promoting sustainable energy and others may be useful sources of data.

- In some cases, international or supranational organizations such as the OECD, the IEA or Eurostat may have assembled relevant statistics on a country that are not easily gleaned from the country's own statistical system.

Statistics from other sources may also be helpful in segregating renewable energy activity from other activity, subject to their quality being evaluated, and with due attention to their consistency with definitions and systems of classification used in official statistical sources.
Useful sources may include, among others:

- Statistics prepared by industry organizations;
- Sectoral studies and other occasional research prepared by, or on behalf of, government;
- Studies prepared by, or on behalf of, industry organizations, workers' organizations and NGOs;
- Academic research; and
- Market research and other private research conducted on a commercial basis.

The extent to which these sources provide sufficient data to adequately describe the renewable energy part of each sector quantitatively for skills anticipation purposes varies greatly between countries. Countries with strong statistical systems and active policy research communities are likely to have far more usable data than countries with weak statistical systems and limited policy research.

However, even in countries that are rich in data and policy analysis, existing data is not normally adequate by itself. It is still necessary to undertake sector level research to bridge the gap in quantitative information.

7.4 Sector level research

Sector level research is required to obtain both quantitative and qualitative information on which to base analysis for skills anticipation.

The minimum quantitative data required for skills anticipation for each renewable energy producing sector includes:

- Data on energy capacity and output by renewable energy technology; and

- Data on employment relating to renewable energy in each technology, in total and disaggregated by occupation.

This data makes it possible to establish relationships between energy capacity/output and employment, both in the energy-producing sector itself and in sectors such as construction and professional services that supply it, and to disaggregate the employment by occupation. (As noted elsewhere, employment in areas such as construction will be related more closely to the rate at which new capacity is installed than to capacity itself.) If projections of future renewable energy capacity and output are available, these relationships can be used to anticipate future employment in each occupation.

These relatively simple models use empirically established relationships between renewable energy capacity/output and employment to project employment, typically distinguishing between:

- Employment associated with manufacture and distribution of equipment, which is modelled as being proportional to the capacity being produced each year;
- Employment associated with project development and construction/installation, which is modelled as proportional to the new capacity being installed each year in the country concerned;
- Employment associated with operation and maintenance of the installations, which is modelled as being proportional to the stock of capacity (or in some cases to annual output); and
- For bioenergy, employment associated with growing, harvesting, transporting and preliminary processing of biomass, which is modelled as being proportional to annual output.

Table 7.1 sets out estimates of the relationships between electricity-generating capacity and employment for some of the main renewable energy technologies, plus coal and natural gas for comparison, drawn from the UNEP *Green economy report* (2008) for illustrative purposes.

In 2009, the Institute for Sustainable Futures at the University of Technology in Sydney undertook a study (Rutovitz and Atherton, 2009) that projected global and regional direct employment to 2030 based on two energy scenarios – one an Energy Revolution scenario proposed by Greenpeace and the European Renewable Energy Council, and a reference scenario base on a projection by the IEA. The methodology and some of the results of the research are summarized here for illustrative purposes.

Table 7.1 Average employment over life of facility
(jobs per megawatt of average capacity*)

	Manufacturing, construction, installation	Operating and maintenance/ fuel processing	Total
Solar Photovoltaic	5.76–6.21	1.20–4.80	6.96–11.01
Wind Power	0.43–2.51	0.27	0.70–2.78
Biomass	0.40	0.38–2.44	0.78–2.84
Coal Fired	0.27	0.74	1.01
Natural Gas Fired	0.25	0.70	0.95

Notes: Based on findings from a range of studies published 2001–2004. The assumed capacity factor is 21 per cent for solar, 35 per cent for wind, 80 per cent for coal and 85 per cent for biomass and natural gas. These factors reflect the fact that most generating equipment does not run at full capacity all the time. The low values for wind and solar reflect the fact that in most locations wind blows strongly only part of the time, and that in the light incident on photovoltaic panels varies depending on time of day, season, cloud cover, latitude and altitude.

* That is, peak capacity multiplied by capacity factor.

Source: UNEP/ILO et al. (2008).

The main inputs to the model were:

- "Projections on installed electrical capacity by technology", taken from the scenarios;
- "Employment factors, which give the number of jobs per MW for each technology", based on evidence from OECD countries;
- "Regional job multipliers ... used to adjust the employment factors in each region to take account of different stages of economic development", or in other words to account for differences in output per person employed between regions;
- "Decline factors, or learning adjustment rates, for each technology" (in other words, factors accounting for improvements in labour productivity, which reduce the employment factors by a given percentage per year).

Adjustments were made to take account of regional differences in activity in producing renewable energy technologies and in producing fossil fuels. The model also included assumptions about "capacity factors" – average output as a percentage of capacity.

The approach taken to identifying employment factors was first to identify employment factors for energy subsectors in the OECD from the literature (significant numbers were found in each case, and these are presented in the report), and then to choose one source for each sector. Table 7.2 summarizes the factors for renewable energy subsectors used in the study. These are reasonably representative of the factor values found in the literature, although there is significant variation between the findings of different sources.

Table 7.2 Employment factors relating capacity and output to employment[19]

	Person Years/MW of Capacity		Jobs/MW of Capacity	Jobs/GWh per annum
	Construction/ Installation	Manufacturing	Operations and Maintenance and Fuel for Generation	Fuel
Solar Photovoltaic	31.9	9.1	0.40	
Wind – Onshore	2.5	12.5	0.40	
Wind – Offshore	4.8	24.0	0.77	
Biomass	3.9	0.4	3.10	0.22
Hydro	10.8	0.5	0.22	
Geothermal	3.1	3.3	0.74	
Solar thermal	6.0	4.0	0.30	
Ocean	9.0	1.0	0.32	

Source: Rutovitz and Atherton (2009).

Table 7.3 summarizes the global employment projections for renewable energy made by the study. It focuses particularly on wind and solar photovoltaic as the study finds that these are the subsectors with the greatest potential to add employment.

The relationships in these fairly simple models vary by major renewable energy technology, and frequently by the specific technology and type of

[19] Note that these numbers are stated on a different basis to those in table 7.1. These are stated on the basis of peak capacity, while those in table 7.1 are stated in terms of average capacity (for example, the average output from a photovoltaic installation may be of the order of 15 per cent of peak output, taking account of factors such as night time). Also, the numbers here are useful for calculating employment at a point in time, while those in table 7.1 are stated on the basis of an average over the lifetime of the installation.

Table 7.3 Renewable energy employment projections (millions) by Rutovitz and Atherton under two scenarios*

		Reference Scenario			(R)evolution Scenario		
		2010	2020	2030	2010	2020	2030
Wind	Construction and Manufacturing	0.29	0.36	0.41	0.43	1.26	1.38
	Operations and Maintenance	0.07	0.15	0.18	0.90	0.43	0.65
Solar Photovoltaic	Construction and Manufacturing	0.08	0.08	0.09	0.18	0.54	1.39
	Operations and Maintenance	0.00	0.01	0.02	0.01	0.06	0.20
Rest of Renewables		1.44	1.81	2.01	0.86	2.74	3.28
Total		1.88	2.41	2.71	2.38	5.03	6.90

Source: Rutovitz and Atherton (2009).

* Note again that this Table is shown for illustrative purposes only, and does not reflect actual outcomes for 2010. WWEA has noted that while its job estimates for wind in 2010 are broadly consistent with the relationships shown in Table 7.2, they are higher than under even the Revolution scenario shown in Table 7.3.

deployment. For example, employment per MW of offshore wind will be different to onshore wind. Employment per GWh will vary between different types of bioenergy plant. Employment in biomass production will vary depending on the crop, the degree of mechanization and the way in which work is organized.

Even where a more complex approach to quantitative analysis is adopted, simpler approaches such as these can easily be used to provide a reality check on the findings.

There are many ways to improve on this very simple approach. An important issue is that a more complete representation of the economics of each renewable sector is often preferable. A representation that takes account of prices, costs and the value of output, as well as employment and energy capacity/output, may be better if the sector is being analysed in isolation, and is necessary if the sector level model is to be integrated into a model of part or all of the wider economy.

Methodologies including surveys of renewable energy businesses and case studies can be used to fill gaps in what is available from existing statistical sources. There are many examples of primary research of this nature being done in existing employment anticipation projects on renewable energy.

In addition to quantitative research into the sector, qualitative research is also required to develop realistic scenarios as to how each core renewable energy sector is likely to develop.

Qualitative research is also important to moving beyond analysis based on existing occupational classifications to take into account new occupations and changes in skills requirements within existing occupations. Beyond this, it is also necessary to identify what training and other interventions might usefully be made to meet identified skills needs.

Projections of demand for energy to be satisfied from renewable sources, which form an essential input into most models of renewable energy employment, also require sector level research. In limited cases, research targeted narrowly on demand for renewable energy may be sufficient by itself, for example if there is a stable existing roadmap for the rollout of renewable energy capacity, perhaps to meet an objective such as the European Union's target of 20 per cent of energy coming from renewable sources by 2020. In more cases, it is necessary to place the sector level research in a wider context that projects energy demand for the economy, and takes a view as to how the split between the main renewable and non-renewable sectors should develop or will develop. In many cases, a view on developments in international trade in energy will also be necessary, as both fuels and electricity are traded internationally to a significant extent.

Issues in sector level analysis in non-renewable energy sectors and in energy-intensive sectors are similar to those for renewable energy sectors, where the research includes such analysis.

Sector level research can be much more detailed than described here. For example, both Australia and Finland have undertaken "engineering" studies on their energy sectors, modelling at a detailed level how it is anticipated that each part of the sector will develop through the transition away from fossil fuels and to renewable energy, and modelling future demand for energy. These engineering studies have been embedded within computable general equilibrium (CGE) macroeconomic models used to evaluate the impact of the transition to renewable energy and of measures designed to promote the transition.

7.5 Linking quantitative analysis across sectors

Some skills research in renewable energy relies almost entirely on primary research to identify and anticipate skills and employment. This approach simplifies the process of bridging between sectors that are seen as separate in standard systems of sectoral classification. Where it is feasible to survey a substantial part of the generating sector itself, the equipment manufacturing industry and the construction and professional services businesses that supply them, it is possible to model their skills requirements without reference to boundaries between sectors that appear in models based on statistics from standard sources.

This approach can suit industry representative organizations that have good access to the industry, and may in any case wish to produce statistics on a basis that suits them and their members.

The approach can also fit within sector level research. While economic modelling usually establishes links between activity in sectors through input–output modelling, it is also possible to use sector level research to specify the link between, for example, investment activity in renewable electricity generation and associated activity (and employment) in construction.

Major publicly commissioned research projects on employment and skills in renewable energy most often embed their representation of renewable energy activity within a representation or model of the whole economy. They use a macroeconomic model that represents the economy as being made up of a significant number of sectors. Renewable energy sectors are represented quantitatively on the basis of findings from sector level research. Other energy sectors and energy-intensive sectors may also be represented on the basis of findings from sector level research; their representation may alternatively be based on standard statistical sources. The representation of other sectors, not directly associated with energy, is also based on standard statistical sources.

A significant practical issue in this is that renewable energy sectoral definitions do not coincide with standard sectoral definitions. In most cases, it is necessary to segregate standard sectors that include significant renewable energy activity between a synthetic renewable energy part and a residual part. In most cases, the renewable energy part will be modelled on the basis of primary research.

Where the renewable energy part is small and its development will not have much impact on the residual part, then the representation of the residual part can be based on standard statistical sources for the sector as a whole. Where the renewable energy part is large, or likely to have an important impact on the residual part, it can be preferable to model the residual part as another synthetic sector on the basis of primary research. For example, as the development of renewable electricity generation will have a major impact on non-renewable electricity generation, it may be preferable to model non-renewable electricity generation on the basis of primary research.

7.6 Linking employment projections to occupational demand projections

Employment projections for each sector modelled can be disaggregated by occupation using a sector-occupation matrix.

- For standard sectors, a sector-occupation matrix can be obtained from labour force survey data.
- For synthetic sectors created for the analysis, the matrix can be based on survey or case study research or can be based on that for a standard sector that is believed to be similar. Another alternative is to use a matrix for the same sector from another country, if this is believed to have a similar occupational profile.

It is good practice to take account of known trends in the occupational structure of the sector, or of changes likely to occur, when projecting the occupational composition of a sector into the future.

Projections of demand by occupation can be developed from projections of employment, by calculating two components of demand.

- Demand related to growth can be calculated by subtracting the previous year's employment from the current year's.
- Replacement demand can be calculated by multiplying employment by an estimate of the rate at which people will have to be replaced because they leave the sector or change occupation. It is not generally possible to be exact about this, as the actual replacement rate will vary depending on the context and will vary over time. It may be possible to obtain data on the current replacement rate as part of a series of case studies or an industry survey.

7.7 Skills needs and training

Where the focus of research is at the level of specific skills required, rather than the numbers needed in each occupation, methodologies rely mainly on qualitative research. In any emerging area of activity, renewable energy included, the skills required by existing occupations change or become specialized in different ways, and new occupations may become important. These issues have to be addressed primarily by qualitative research, using methods such as company surveys, interviews, case studies or focus group discussion. Some examples are described later in this section of the report.

Qualitative analysis of this sort is also required to understand possible sources of skills supply, and to understand how these can best meet demand. There is seldom a single possible source of supply to be considered. There are choices to be made about whether to look to initial education and training, to upgrading or adapting the skills of the existing workforce, to recruiting from other sectors or indeed the unemployed or people who are inactive in the labour market, or to recruiting skilled people from outside the country.

Once the most viable source or sources of labour have been identified, it is often necessary to research in detail what the skills requirements will be, to inform providers of training or education, to inform the recruitment effort, or to inform training within businesses. This, again, requires qualitative research.

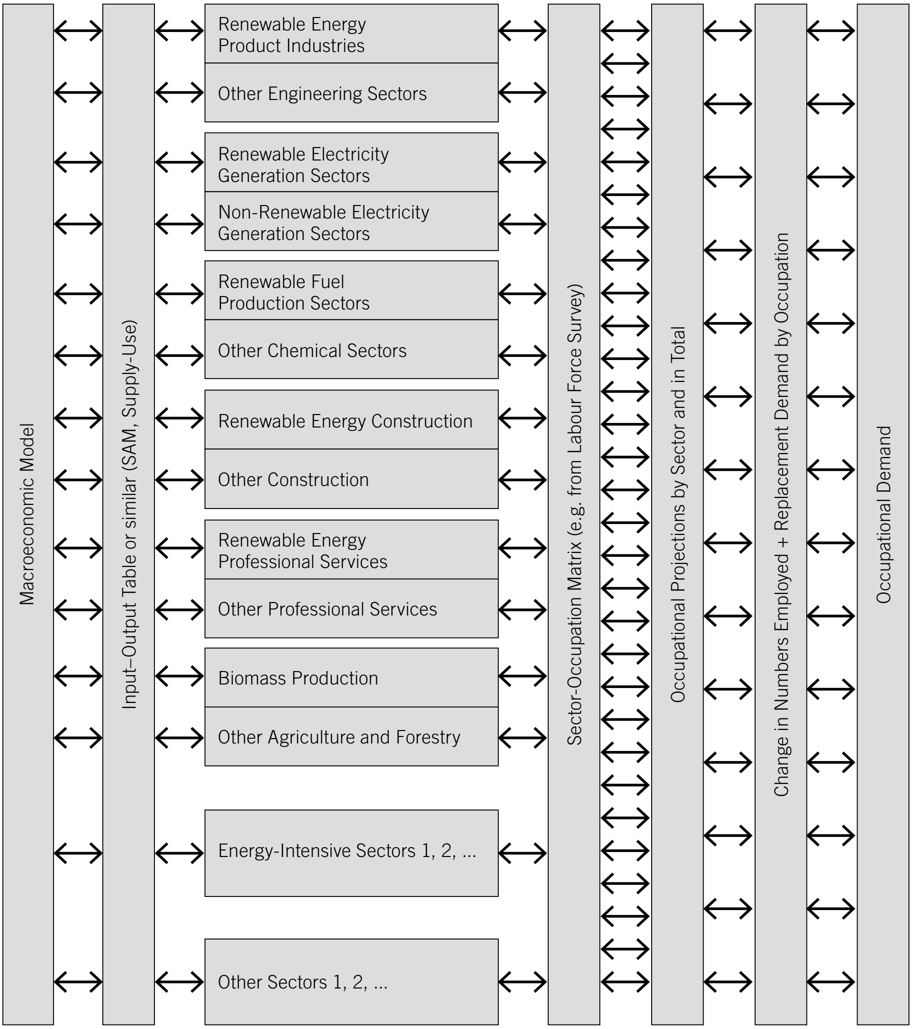
Matching quantitative projections of demand for skills against projections of skills supply is complex, and for this reason skills studies frequently avoid it. Doing it successfully requires a very good qualitative understanding of the sources of supply, how the skills they develop compare with the actual skill needs of employers, and what the impact of competing sources of demand for the same skills is likely to be on availability and labour costs. Again, this requires strong qualitative research.

7.8 An idealized quantitative model framework

The detailed structure of the models reviewed varies considerably. Figure 7.1 presents an idealized framework. In practice, many models omit parts of it, or approach them differently. As presented, the framework assumes that the model is built around standard statistics, supplemented by sector level research in the main renewable energy sectors. Some of the standard sector classifications are segregated into two parts – a synthetic renewable energy part and an "other" part.

The list of sectors to be segregated is simplified here, for example distinguishing between renewable energy product industries and other engineering sectors, rather than listing all the main ISIC sectors that produce renewable energy products. In practice, some of these sectors might be modelled at the level of their component parts within an analysis. For example, renewable electricity-generating sectors might be disaggregated between wind, solar, geothermal, hydro and bioenergy. In practice, also, some sectors shown as being segregated here might instead be modelled as single sectors.

Figure 7.1. Idealized framework for quantitative methodologies in renewable energy



Source: Authors.

Figure 7.1 lists six segregated sectors, each composed partly of renewable energy industries, along with two other groupings of sectors – energy-intensive sectors and other sectors. Together, all of these sectors represent the full economy.

Figure 7.1 depicts these sectors fitting into a macroeconomic model, through the medium of an input–output table. A supply-use table or a social accounting matrix can be used instead. A social accounting matrix is an input–output table with additional variables to incorporate a more complete representation of the economy.

The macroeconomic model may, at simplest be an input–output model. A social accounting matrix model or SAM is more complex. A dynamic social accounting matrix model or DySAM adds dynamic elements to a SAM to depict changes in sectors and the economy over time, such as improvements in productivity. A computable general equilibrium model or CGE is another possibility, but because of the complexity of producing and validating these models, it is only likely to be feasible if an existing CGE model can be adapted.

SAM and CGE models can be constructed so as to incorporate information on energy flows alongside information on economic flows.

7.9 The role of social dialogue in the identification of skills

Adequate and timely delivery of training in renewable energies depends to a large extent on institutional arrangements to anticipate demand and provide training to meet this demand. Countries are either using existing systems or putting in place new structures or activities to anticipate and provide for skill needs in renewable energy. Interaction and partnership between private companies, workers' representatives and training providers plays an important role in skills identification and anticipation.

Organizations of workers and employers are engaged in dialogue on the transition to the low carbon economy in many countries, for example in Spanish social dialogue roundtables for the Kyoto Protocol commitments. They also participate in tripartite systems to adapt or create new curricula for renewable energies, such as in the German and Danish apprenticeship systems. In Central America a group of technical and vocational education and training (TVET) institutions from different countries, all governed by tripartite boards, have cooperated in designing training standards and curricula for installers and maintainers of wind energy systems, and for photovoltaic systems installers and maintainers.

Skills councils – employer-led organizations in specific economic sectors whose activities are usually co-sponsored by the state – also play an important role. In the United Kingdom, a number of UK Sector Skills Councils have convened to form the Renewable Energy Skills Group. The group provides a forum for coordinating a Renewable Energy Skills Strategy which aims to take account of the requirements across the supply chain from initial research, to installation and maintenance and disposal at the end of life. In the Republic of Korea, two new sector skills councils have been created: a Sector Council Human Resource Development for New Renewable Energy, and one for Green Finance. Both councils provide short training courses: the former on topics such as solar energy technology and the Clean Development Mechanism; the latter on green industry trends, risk analysis, green finance and social accounting and sustainability assessment (Strietska et al., 2011).

There are examples of newly created bodies with a mandate to identify skills needs specifically in the renewable energy sector. In Canada, for example, a Renewable Energy Advisory Committee on Training exists with representation from industry, colleges and Natural Resources Canada, a government agency related to the Ministry of Natural Resources. The Committee coordinated the development of a strategy for renewable energy training in the country covering the following technologies: solar thermal and photovoltaics, low-emitting and high-efficiency biomass combustion, ground source heat pump, wind and small-scale hydro (Delphi Group, 2007).

In France, the Comité de Liaison Énergies Renouvelables (CLER) is an association of companies, public institutions, trade unions and other organizations that promotes renewable energies and organizes annual meetings with training institutions to share methods, best practices and to create a platform of dialogue.

In the US, the American Wind Energy Association (AWEA) established an Education Working Group through which industry members and the educational community interact to develop training strategies for the industry. Up to now they have developed, among others: job and career training programmes for Community and Technical Colleges; academic and career development programmes at undergraduate and graduate institutions; and scholarship opportunities through the "AWEA Educational Scholarship Program".[20]

Colleges have also set up advisory committees to identify changes in skill needs. The Golden West College advisory committee is considered exemplary for other colleges offering training programmes in renewable energy. It comprises industry representatives, city governmental officials, community members, students and renewable energy organizations in the country and supports curricula development and access to equipment for practical training (Lindstrom, 2007).

[20] American Wind Energy Association website: http://archive.awea.org/education/workinggroup/goals.html

Section 8

Conclusions

8.1 Introduction

This section draws conclusions in the following areas:

- Need for a skills component to renewable energy planning
- Pacing investment
- Broad skills response approaches on projects of significant scale
- Broad skills for smaller projects
- Renewable energy skills planning for developing countries
- Portable skills
- Standard training content
- Skills anticipation
- Just transition
- Quality of employment in renewable energy
- Corporate social responsibility in large-scale renewable energy projects in developing countries
- Social dialogue in design and delivery of skills interventions for renewable energy
- Supply of trainers
- Government strategies

8.2 Need for a skills component to renewable energy planning

It is clear from the research undertaken that shortages and surpluses of skills are a natural outcome of weak coordination between large initiatives to develop renewable energy and potential sources of skills supply including providers of education and training.

This is a bigger issue with renewable energy than with most other sectors because of the following.

- The project nature of much of the work can lead to booms and busts in project development and construction/installation work within a region or a country, particularly if there is no coordination between larger projects to smooth activity over time.
- Employment in operations and maintenance may increase in something approaching a step fashion each time significant new capacity is commissioned.
- As most net demand for people occurs at the time of the increase in employment, this can lead to spikes in demand. These may be interspersed by periods of much lower demand driven by smaller projects and by the need to replace people moving to other occupations or sectors.

In most countries, regular skills supply arrangements are not designed to respond efficiently to a highly variable pattern such as this from an industry that may be new to the country and unfamiliar to providers of education and training and policy-makers. If renewable energy sectors are to satisfy their skills needs efficiently, it is necessary that plans to install new capacity should include explicit plans as to where they will be able to source them, and what providers of education and training, employment services and others will have to do to ensure that the skills are available when needed.

These specific issues are likely to be less significant in the case of renewable energy industries delivering small projects such as building level installations of solar water heating, photovoltaic panels and heat pumps. Even with these, however, demand is frequently driven by government subsidies, spikes in energy prices and organized programmes to install the technologies across large numbers of buildings, which can also generate booms and busts in demand for people. It is, therefore, necessary that planning for renewable energy initiatives at this level should also include a skills component.

8.3 Pacing investment

When planning the development of renewable energy capacity, one of the major concerns should be an effort to smooth the pace of investment over time so as to provide stable employment for workers, avoid periods of serious labour shortages for employers, and make future demand for labour more predictable for providers of training and education and their current and prospective students.

It will not always be feasible to do this. However, where it is possible, a gradual ramp-up in the rate at which new capacity is added will allow the sector to accumulate skilled people over time, avoiding an initial spike in demand for people in project development, construction and installation that may be difficult to satisfy. Allowing the rate at which new capacity is installed to plateau eventually will allow the installed base to continue growing, with only a limited demand for additional people in project development, construction and installation, but with a steady demand for additional people to work in operations and maintenance.

8.4 Broad skills response approaches on projects of significant scale

While there is no single best way to provide the skills required in renewable energy, some approaches are better suited to particular parts of the value chain than others.

Project development

The main requirements in this part of the value chain are for people with high-level skills in diverse professional areas who already have significant to substantial working experience. The extent to which they need skills and knowledge specific to renewable energy varies.

In a developed country it will usually be possible to contract in suitable skills locally in the less technically specialist areas, and for their employers to source any supplementary training they need locally or internationally. Very specialist technical skills in a technology new to the country may be sourced internationally.

Short courses, conferences and seminars designed to provide professionals and renewable energy business managers with timely knowledge on important issues specific to their renewable energy sector will be required. These should be promoted by organizations interested in promoting renewable energy, whether industry representative bodies, professional groupings or government agencies responsible for renewable energy.

Construction and installation

Skills requirements at this stage in the value chain vary between subsectors, but the greatest requirement on projects of significant scale is for civil, mechanical and electrical engineers, technicians and construction workers to undertake preparatory works, and to commission the equipment when it is installed. They may also be involved in actual installation, or this may be undertaken by the supplier of the equipment.

Most of the skills required at this stage in the value chain are available in the construction sectors and in construction-related professional services businesses of developed and emerging countries, although to an extent this depends on the renewable energy technology concerned and civil engineering works undertaken in the country previously – there may be a need for additional learning to enable those skills to be used in the new context.

When deciding whether to provide initial education and training targeted on construction and installation work for renewable energy, in addition to considering whether there is sufficient lead time and certainty to justify it, it is necessary to take a view on career prospects. It may be difficult to justify providing very specialized initial education and training in support of a large project or series of projects that are likely to only last a few years, or where employment opportunities are likely to be volatile. Where this is the case, it favours providing skilled people already in the labour force with additional training in preference to providing initial education and training.

Operations and maintenance

Once they are constructed, installed and commissioned, most renewable energy installations require small numbers of people to operate and maintain them in comparison with the numbers involved in construction and installation. However, where there is continuing investment, the installed capacity and the numbers employed in operations and maintenance add up over time. The jobs involved are likely to be stable (although subject to some reduction from productivity improvements). They may last for the operating lifespan of the installation, which may be 20–30 years, or more if the site undergoes a refit.

Some of these jobs are likely to be filled by people with technical skills who have been involved in installation work. However, the jobs are likely to also be suited to people with relevant technician and craft skills. It is likely that local providers of technical vocational education and training will be able to assemble the capabilities to provide suitable courses or support suitable apprenticeships.

Biomass production

Once a bioenergy plant using grown biomass (as opposed to organic waste) is operating, it will require a supply of biomass over its operating life. Most of the employment will be in relatively low skilled agricultural (including forestry), harvesting and transport jobs. The people taking these jobs will mostly be from among the local population, and many of them may have worked the same land in other forms of agricultural enterprise. They will typically need a relatively small amount of training to prepare them for the new crop, although if the new operation is more mechanized than the enterprise it replaces there may be a greater need for upskilling to operate harvesting equipment and transport vehicles. Training may be provided on site or at a local vocational or agricultural training centre.

Equipment manufacture and distribution

The issues in the supply of skills for manufacture and distribution of renewable energy technologies are essentially those of any major engineering-based capital goods industry.
General issues of significance include:

- Shortages of engineers in many developed countries;
- The relatively strong supply of engineering skills in many emerging economies which is contributing to the growth of renewable energy technology industries in countries including China; and
- The lack of a strong tradition of mechanical, electrical and electronic engineering skills in many developing countries, which puts them at a disadvantage in building businesses or attracting foreign direct investment in more sophisticated and higher value added equipment manufacture activities.

8.5 Broad skills for smaller projects

While renewable energy capacity of significant scale are very important, there is also substantial activity in smaller projects, often targeted on supplying the needs of a single building or group of buildings.

Small-scale installations may include photovoltaic panels, solar water heating, small hydropower, biomass heating or a heat pump to supply a single building. Installations of these types require combinations of construction craft skills, such as plumber, electrician and roofer, and may be designed and delivered by one craftsperson skilled in all of these areas or by a combination of people from different craft backgrounds. Training requirements are either specialist training in the technology (such as photovoltaic installer courses) or some additional training for people in existing construction craft occupations to prepare them to work together in installing the technology.

This is a bigger issue with solar energy than with other renewable energy technologies, as a substantial share of photovoltaic panels are installed at the level of individual buildings, and most solar water heating is also installed at the building level.

Renewable energy installations in larger buildings can be much more complex, both in terms of using complex, often proprietary, renewable energy and energy efficiency technologies and in terms of integrating the operation and control of those technologies to produce a carbon-efficient, comfortable building with low running costs.

A key skills issue for installations of this type is that installers should have a broad understanding of the technologies, either so that they can participate in all aspects of the installation or so that they can cooperate effectively with specialists in other areas to install the technologies efficiently and to a high standard of quality. There is, in many cases, a need for broader training for people who will undertake this installation work at a technician or skilled crafts level.

University courses that cover multiple renewable energy and energy efficiency technologies have become common, and play an important role at the design level.

8.6 Renewable energy skills planning for developing countries

Large-scale projects

Large-scale renewable energy projects in developing countries will be an important feature of the transition to renewable energy. Many of the best unexploited sites for hydropower are in developing countries. There is considerable interest in using deserts, many of them in developing countries, as sites for generation of solar power, both using photovoltaic and concentrated solar power technologies. Many developing countries have good wind, geothermal, biomass or ocean resources that they could potentially exploit on a large scale.

A key challenge for these countries is to maximize the local economic benefits of these investments. To the extent that they can use their own people rather than expatriates without loss of effectiveness, direct economic local benefits will be greater, project costs should be lower and they will improve their human capital base.

In developing countries new to a renewable energy technology, it is likely to be necessary to contract in skills in project development from outside the country, and much of the work may even be carried out outside the country. If there is scope for a succession of projects, as the country gains experience it should become possible for more of this work to be undertaken in-country with decreasing reliance on international expertise.

In a developing country, the higher level skills required for construction or installation work may or may not be available, depending on the country's skills profile, on the renewable energy technology, and on works undertaken in the country previously. In many cases, it is necessary to contract in people from elsewhere to do much or most of the high-skilled professional level work. Depending on the supply of available skills, it may also be necessary to contract people from elsewhere to undertake much of the medium-skilled work too – work at the technician, supervisor and specialist skilled craft level.

Where the broad skills required are available, training requirements are mainly for short courses to prepare people at all skill levels to deploy the skills they already have in the new context. In many cases, there will not be enough time available to train people from scratch, even if that approach is preferred.

If the skills are not available, contracting-in skills from international sources may be necessary. However, if there is both a long lead time and certainty in the project planning process it may be possible to train local people for entry level positions in mid-level occupations, to prepare engineering students to work in entry level engineering roles, and to place graduate engineers internationally, on postgraduate programmes or in project engineering employment to obtain the experience they would need to take up more senior roles.

Decentralized electrification

In developing countries, renewable sources of electricity are frequently used to bring electrification to communities that are off the country's electrical grid, with no immediate prospect of being connected, often with support from NGOs. This may be achieved through domestic scale installation of technologies such as solar panels, or through larger community scale installations of bioenergy plants, small hydropower schemes, community solar schemes and other initiatives. Achieving this requires a significant technology transfer effort, including training of local people to operate and maintain the equipment, and to manage the operation.

Opportunities from electrification

In many cases, installation of renewable electricity generating capacity in developing countries will be associated with extending electrification to more of the country's communities, many of them rural. Electrification offers opportunities to communities to establish new businesses and services. Education of members of the community in entrepreneurship and in identifying businesses and services that have been successful elsewhere under comparable conditions forms a useful complement to the provision of electricity.

8.7 Portable skills

It is important that education and training targeted on the renewable energy sector should invest in skills that are portable, and can be exploited in other sectors if demand is insufficient in renewable energy.

Even with efforts to smooth the flow of new renewable energy investment within a region, employment in renewable energy project development, construction and installation may be volatile. Limited availability of sites or resources may mean that capacity in a region reaches saturation, ending the scope for new installations. A change in the investment environment may lead to a slowdown in installation of new capacity. Technical constraints may limit the new electricity-generating capacity that can be connected to the electricity grid.

In operations and maintenance, interruptions to the development of new capacity such as these will not generally cut existing employment, but they may result in periods when there is little scope to employ new graduates of training courses preparing students to work in the area.

For these reasons, it is important that education and training courses targeted on the renewable energy sector should be built around the core of a qualification that will be useful in a broader range of sectors, with specialist content relating to renewable energy supplementing that core. The training should have a significant focus on core skills – those softer skills in areas such as communication, problem solving and team working that are in any case essential in the renewable energy context.

Technician courses should at their core be courses in mechanical, electrical and/or control engineering, even if they also include content specifically relevant to renewable energy. Training targeted on the construction phase should at its core be construction industry training, even if it has renewable energy content.

Benefits to ensuring that workers have portable skills that can also be exploited in other sectors include:

- Better career security for those employed in the sector, or training to work in the sector; and
- People with the flexibility to tackle a broader range of challenges than highly specialist training might allow.

8.8 Standard training content

It is a characteristic of renewable energy that a large part of the technical skill sets required vary little between the countries in which technologies are deployed. Suppliers of wind turbines, solar panels, hydroelectric turbines, equipment for geothermal applications and for the various bioenergy technologies sell internationally, and often globally. The skills required to install, operate and maintain them are similar wherever they are deployed. While differences in equipment design between competing suppliers mean that workers often need additional training to move from working on the products of one supplier to another, the broad skills requirements are similar.

The pattern through which employment develops in renewable energy sectors poses challenges to providers of training and education. The usual approach to course development for many providers is that they will spend a significant period of time understanding an emerging skills requirement, designing a course, and assembling the capabilities they need to teach it. They will then hope to be able to run it regularly for at least a number of years to take advantage of their up-front investment in development.

This approach often does not fit well with the employment demands of the renewable energy sector. Demand for skilled people can appear without very much notice. The volume of demand can sometimes be quite volatile. Even in operations and maintenance, where employment tends to be stable, there may be pauses in recruitment, and numbers employed may hit a plateau after a few years resulting in much lower demand for additional people.

Because skills requirements are fairly uniform across national and regional boundaries, the international renewable energy sector has an opportunity to make it easier for providers of education and training to respond. It could provide standard content, advice and even training to providers, allowing them to cut the time required to start up a new course, and helping them to ensure the course is relevant and of high quality. With less up-front investment in course development, providers could more easily accept any risk that demand for the course will be volatile or will not last.

In most national contexts, providers of education and training will wish to tailor courses to local need to some extent, and to provide qualifications in keeping with existing qualification arrangements in their country. At the same time, there is scope to provide an internationally recognized industry certification to complement the national qualification, recognizing that graduates have covered the standard content, and have acquired the standard skills required to work in a renewable energy sector.

A possible response to this challenge would be that the major international renewable industry associations would take the initiative to establish a council of stakeholders, analogous to a national level sector skills council, to:

- Establish or recognize industry certifications for core occupations across the renewable energy sectors; and
- Put a programme of support in place to make standard content, advice and training available to providers of education and training in countries where there is a need to establish, improve or broaden course provision to meet the sector's needs in that country.

8.9 Skills anticipation

Skills anticipation in renewable energy is important.

Part of the reason for its importance is that it is more tractable than in most other sectors.

- Future patterns of installation are well researched in many countries, and can be researched well in others. As large- and medium-scale projects are often planned a number of years in advance, projections can be based on detailed and fairly reliable information. Even with larger numbers of smaller projects, it may be possible for research to produce useful guidance on future rates of installation.
- For each type of technology, it is possible, based on empirical research, to identify a detailed and fairly reliable relationship between capacity and both numbers employed and the occupational and skills composition of the employment. Employment in project development, construction and installation can be linked to the rate at which new capacity is being installed, either directly or through the more complex modelling approaches described in the report. Employment in operations and maintenance, and in biomass production in the case of bioenergy, can be linked to the installed capacity that is in operation.

Another reason for its importance is that patterns of demand for people may not vary just in small increases and small decreases as they often do in more mature sectors. The scope for a substantial mismatch between supply and demand is therefore greater.

There is value in having all the main stakeholders involved in skills anticipation to ensure that all available information is brought to bear from renewable energy businesses themselves, from workers' representatives and providers of education and training. It is important that providers of education and training related to renewable energy, including employer and workers' organizations, should understand the stream of future employment opportunities that will be available to their graduates.

8.10 Just Transition

As the transition to renewable energy progresses, it seems inevitable that there will be substantial reductions in employment in fossil energy. How extensive these reductions will be is uncertain, and depends on the extent to which renewables replace fossil sources of energy. Even the IEA Blue Map scenario referenced earlier envisages that fossil fuel fired electricity generation will continue to be important to 2050, with its impact on carbon emissions mitigated by the use of carbon capture and storage technologies.

As with any industries whose activities are wound down as a matter of public policy, it is important that the transition be managed in a manner that is just to employees.

That implies among other points that:

- The wind-down should take place over an extended period to minimize the shock; and
- Workers should have the opportunity to learn new skills, or to learn to apply their skills in other employment contexts.

Some fossil energy industry skills are particularly relevant to renewable energy:

- Many of the skills in operating and maintaining fossil power stations can be adapted to operating and maintaining other forms of generating capacity.
- Skills in drilling used in the oil industry are essentially the same as those required for geothermal energy.

Where geographic constraints allow, people with transferrable skills such as these, also in other declining sectors outside the fossil fuel industry, should be offered retraining to work in renewable energy as their existing jobs are eliminated.

8.11 Quality of employment in renewable energy

The transition from traditional sources of energy to renewable energy is changing the profile of skills in the energy sector, but is also changing the industry framework within which people are employed. The energy sector has traditionally been highly concentrated in most countries, has been capital-intensive, and often with significant government involvement. The large energy businesses that this industry structure produced have mostly been relatively good employers that offer Decent Working conditions and fair levels of pay.

The emergence of renewable energy has changed these structures in significant ways. Energy industries are much more fragmented than in the past, much of the employment is in new businesses and industries that do not have an established history, and more work is project-based. There is evidence that this is putting pressure on the quality of employment in many contexts.

Growing and harvesting of biomass is a relatively labour-intensive activity that is growing fast in the context of the transition. There is evidence of significant problems with the quality of employment in biomass production and harvesting, particularly in developing countries, and particularly in areas and with biomass crops where there has been little investment in mechanization.

There is a need for policy-makers promoting the transition to renewable energy to take account of Decent Work principles when designing policies and interventions, and to ensure that workers have the opportunity to organize to pursue high quality working conditions. In areas where there is a significant risk that the quality of working conditions will fall below Decent Work criteria, there is a particular need to enforce labour law effectively.

8.12 Corporate social responsibility in large-scale renewable energy projects in developing countries

Large-scale renewable energy projects in developing countries have a significant impact on the local population. They bring jobs to the area, some of which may go to locals, and bring in spending power that tends to boost economic activity. They may displace existing activity, as with land being flooded for hydropower projects. They bring significant or substantial numbers of outsiders into the area at the development and construction stage, and may leave numbers that are locally significant during the operations and maintenance phase.

Local goodwill is usually valuable to developers and operators of renewable energy projects, because it facilitates the smooth running of operations, it is positive for relationships with regulators, and it is positive for wider reputational reasons.

It is, therefore, important both to the local population and to the renewable energy project itself that renewable energy projects are developed and operated in a responsible manner that takes account of the project's wider social impact. Large-scale renewable energy projects should have a strategy for corporate social responsibility.

Corporate social responsibilty strategies have significant skills implications. Maximizing the access of local people to employment opportunities associated with the renewable energy project requires targeted interventions to develop the skills required. In a developing country context where the local population typically has a weak qualifications profile, this requires a particular focus on low- and medium-level skills, initially in construction, and then in operations and maintenance. In the case of bioenergy operations, where growing and harvesting of biomass will provide substantial employment for local people, the need is to ensure the jobs are decent, and that any negative impacts that arise from displacement of other economic activity be mitigated by applying Just Transition principles.

In many cases, organizations developing and operating large-scale renewable energy projects in developing countries undertake economic and social development projects for the benefit of the local population that are not directly essential to implement the project. These can make a valuable contribution locally, particularly where they give rise to Decent Work opportunities.

8.13 Social dialogue in design and delivery of skills interventions for renewable energy

Governments, employers and workers' organizations have a shared interest in tackling skills gaps in the green building value chain. In many countries, they are already involved jointly or independently in anticipating and responding to the need for skills for green building, frequently along with providers of education and training related to construction, professional bodies and civil society organizations concerned with green building.

Governments, employer organizations and workers' organizations all have capabilities that can be applied to meeting the need for skills:

- In most countries, all have relevant training and education capabilities.
- Employers and workers' organizations have direct access to workers, and have a first-hand understanding and expertise in the nature of skills gaps and how they can most practicably be addressed. They bring different, but complementary, perspectives.
- Government sets the regulatory framework, and in many cases intervenes, directly and through indirect policy instruments, in support of the transition to green building.

For these reasons, dialogue between the social partners on anticipating and meeting the skills challenge is required to design and implement the best possible skills development responses.

8.14 Supply of trainers

Frequently, one of the main choke points constraining employers and providers of education and training from responding sufficiently quickly to emerging skills requirements in renewable energy industries is a shortage of suitable trainers and educators. As demand for people to work in renewable energy often emerges relatively suddenly, there is often a need for education and training institutions to source the trainers and educators they need at fairly short notice, to allow them to respond to emerging skills requirements in a timely manner.

In many cases, institutions already have trainers and educators expert in providing training for occupations that share skills with renewable energy occupations, and can address their need for trainers in renewable energy through initiatives to provide them with supplementary training. Collaboration with institutions that are already expert in training in renewable energy is a practical way to achieve this, through staff exchanges or placements, and through sharing of course materials. Collaboration with industry and the development of facilities for practical work (such as model scale digestion or wind turbine facilities) by students also make an important contribution to development of trainer skills. Good responses may include the following:

- Staff placements or staff exchanges at education and training institutions already expert in providing education and training in renewable energy skills.
- Provision of train-the-trainer or continuing professional development courses for trainers and educators. These will be particularly appropriate if a system of commonly recognized qualifications is established in renewable energy.
- Conferences and seminars on new techniques and technologies, targeted on trainers and educators. These are particularly appropriate where trainers and educators design course content and choose pedagogical approaches themselves.
- Support for research relating to renewable energy. Research is one of the main mechanisms through which teachers in higher education update their knowledge, allowing them to maintain and improve the relevance of their teaching.
- Initiatives to research good practice in training and education for green building. For example, the UK's Higher Education Academy, has an Education for Sustainable Development project. The European Union has contributed to work of this sort through the Intelligent Energy Europe programme, which has supported projects addressing a range of occupational areas including, among others installation of small scale renewable energy installations.

Governments and agencies responsible for promoting green building should invest the modest resources required to support responses such as these in a way that is appropriate to their country's institutional framework. Given the significance of the international dimension, supranational and international organizations such as the EC and the ILO should work to promote cooperation and collaboration between providers of education and training in different countries.

8.15 Government strategies

Skills have a strategically important role in developing renewable energy. They are so important to enabling the success other types of strategy for renewable energy that every government initiative to promote the transition to renewable energy should have a skills component to it.

Governments should consider addressing the following types of skills-related issues in their strategies to progress the transition to renewable energy:

- The need to pace investment in renewable energy capacity so as to smooth demand for skills over time, avoiding a pattern of booms and busts in the labour market detrimental to the interests of workers, employers and the efficient deployment of renewable energy.
- The need for installers of renewable energy technologies to have a breadth of skills to undertake projects requiring a mix of different types of skill, either so that each can do the job by themselves, or so that they can cooperate more effectively with others with complementary skills.
- The particular need for skills planning where developing countries are planning large scale renewable energy investments.
- The need for skills in renewable energy to be portable, allowing workers to transition to new generations of renewable energy technology, or to move to other types of activity if labour market demand falls.
- The need for international standards in skills and training for many types of skill in renewable energy.
- The need to engage in skills anticipation in renewable energy.
- The need for policy to focus on achieving a Just Transition in energy industries where renewable energy is displacing other sources of energy.
- The need for policy-makers to focus on ensuring that the transition to renewable energy generates high quality employment.

- The need to ensure that large scale renewable energy projects in developing countries have an effective strategy for corporate social responsibility.
- The need for social dialogue in the design and delivery of skills interventions for green building.

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Appendix 1

Survey Respondents

Type of organization	Name of Organization	Country	Associated Partner
Training Institution	BZEE e.v. Bildungszentrum für Erneuerbare Energien, Koordinationsbüro Husum	Germany	WWEA
Training Institution	renac Renewables Academy AG	Germany	WWEA
Training Institution	Department of Electrical Engineering, National Institute of Technical Teacher Training& Research	India	WWEA
Training Institution	Central Department of Physics, Tribhuvan University	Nepal	WWEA
Training Institution	Kozminski University (International Office). The Centre for Industrial Productivity and Sustainability	Poland	WWEA
Training Institution	artefact GmbH International training centre for sustainable development	Germany	WWEA
Training Institution	Centro de Estudio de los Recursos Energitocos, Universidad de Magallanes CERE-UMAG	Chile	WWEA
Training Institution	Solar Energy International	USA	ISES
Training Institution	University of Freibert	Germany	ISES
Training Institution	Institute of Nuclear and New Energy Technology, Tsinghua University	China	WBA
Training Institution	Liaoning Institute of Energy Resources	China	WBA

Type of organization	Name of Organization	Country	Associated Partner
Training Institution	Centre for Energy, Indian Institute of Technology, Guwahati	India	WBA
Training Institution	School of Energy Studies, Jadavpur University	India	WBA
Training Institution	Energy Field of Study, Asian Institute of Technology	Thailand	WBA
Training Institution	BTG Biomass Technology Group BV	Netherlands	WBA
Training Institution	Kafue Gorges Regional Training Centre	Zambia	IHA
Training Institution	International Centre for Hydropower	Norway	IHA
Training Institution	UNU Geothermal Training Program	Iceland	IGA
Training Institution	Hochschule Bochum	Germany	IGA
Employer	Ammonit Gesellschaft für Messtechnik GmbH	Germany	WWEA
Employer	BGZ Beteilungsgessellschaft Zukunftsenergien AG	Germany	WWEA
Employer	Renewable Resources (Photovoltaict) Ltd	Pakistan	WWEA
Employer	KWB-Kraft und Wärme aus Biomasse GmbH	Austria	WBA
Employer	Benet OY Limited Company	Finland	WBA
Employer	Pure Energy Professionals Ltd	UK	WBA
Employer	Vapo	Finland	WBA
Employer	Voith Hydro	Germany	IHA
Employer	Ethiopia Electrical Power Corporation (EEPCo)	Ethiopia	IHA
Employer	Tractebel Energia SA	Brazil	IHA
Employer	Itaipu Binacional	Brazil	IHA
Employer	Geothermal-electric division of the Federal Commission for Electricity (CFE)	Mexico	IGA
Employer	KUTh Energy Ltd	Australia	IGA
Association	Mongolian Wind Energy Association	Mongolia	WWEA
Association	APEE - Association of producers of Ecological Energy for Bulgaria	Bulgaria	WWEA
Association	Bulgarian Wind Power Association	Bulgaria	WWEA
Association	Chinese Wind Energy Association	China	WWEA

Type of organization	Name of Organization	Country	Associated Partner
Association	Canadian Wind Energy Association	Canada	WWEA
Association	European Solar Thermal Industry Federation	Belgium	ISES
Association	Interstate Renewable Energy Council	USA	ISES
Association	American Council on Renewable Energy	USA	WBA
Association	European Biomass Association	Belgium	WBA
Association	National Hydropower Association	USA	IHA
Association	E.ON Wasserkraft GmbH	Germany	IHA
Association	Alternate Hydro Energy Centre (AHEC)	India	IHA

Appendix 2

Interview Guidelines

Introduction to Interviews

Thank you for your time quantifying solar energy sector workforce status and needs.

We are conducting research on this, in collaboration with the United Nations International Labour Organization. The final report due this spring will help direct further support for training programs and policies for all renewable energy sectors. Our focus is the solar energy sector.

The report will include:

1. Background – analyses, data, info, trends for solar sector
2. Drivers of change in solar sector – policies, regulations, innovation, etc. and challenges/opportunities for skills
3. Current state of workforce and occupational demand – core occupations, demand for these, and how they are being identified
4. Skill shortages – What are they and why are they there (e.g. education, training, ...?)
5. Measures to address demand – What training being offered, partnerships with other organizations, recruitment from other sectors
6. Key policy recommendations – for stakeholders, education/training, further research/analyses

We are asking training providers, businesses and associations to help with this. You may have already seen our detailed questionnaire, sent out recently via email. Since your input is valuable to our study, we are following up with this call.

We have simplified the questions and hope to take up a few minutes of your time.

As a participant, you will be acknowledged and will receive a copy of the report.

What is the best way to acknowledge you and your organization in our report? (name, type, address, countries covered by your efforts, other key information)

Let's now go through the questions specific to your group.

We welcome your comments on other aspects not covered directly in the questions.

Overview Questions: These relate back to the broad topics of concern.

- Background – What do you see as trends in the sector?
- Drivers of Change – What do you see as the major drivers of change?
- Current State of Workforce – What do you perceive as the current state?
- Skill Shortages – What do you see as the major skill shortages?
- Measures to Meet Demand – How are needs being met?
- Recommendations – How could workforce development be improved?

Training Providers – Key Questions

1. Is your organization mainly involved in RE training or do you do other things? If so, what?
2. What type of RE job skill set training do you offer? Do you provide training related to other more general skills? If so, what?
3. Have your curricula and specific course offerings and content related to RE changed over the past 5 years? If so, why and how?
4. How do you track success of students, and changes in the skills being demanded by the RE sector?
5. Do you team up with other organizations to track, prepare and/or implement your programs?
6. How would you describe your RE students this year and how has this changed over the past 5 years?

   a. First time students versus people coming to be retrained (total number in each currently)
   b. Male versus female
   c. In country versus out of country (what other countries mainly)

7. What is your general perception about training capacity for RE (in your country, the sector)?

Employers – Key Questions

1. What issues have the most significant impact on your activities and on employment and what has been the impact? (e.g., Policies related to climate change, other regulations, response to economic crisis, consumer demand, skills shortages, global trade, R&D, public opinion on RE and fossil fuels)
2. What has been the employment trend in your company (now versus 5 years ago)? Percentage male versus female, core types of jobs, training requirements for these jobs, special qualifications needed, training providers (i.e., you or some other org), in-country or out of country (which countries), percentage of your workforce that has had experience doing similar work in other sectors before starting to work in renewable energy (what types of work and in what sectors)
3. What do you see are the main human resource challenges for employers in the RE sector? Is lack of adequate training a large challenge? How have the challenges changed over the past 5 years?
4. Do you expect the number of people trained in the skills your sector needs to be sufficient, or do you see a gap and is it growing? What occupations are most difficult to fill with qualified workers? What skills are most lacking for the core occupations?

Associations – Key Questions

What is your mission and membership type and level?

Where do you have the most impact (e.g., policies, regulation, economics, consumer demand, skills shortages, global trade, new R&D, public opinion, other) and what is the impact?

Do you have information on the skills/occupations of your members' workforces? If so, how many employed 5 years ago versus now; what is the breakdown of employment by occupational group (managers, professionals, technical, clerical, services and sales, craft and trade, other); and as of December 2010, approximately how many do your members employ indirectly through service providers and businesses involved in installing new capacity on your behalf? What are core occupations in your members business, or in businesses that they rely upon? What are the main corresponding tasks? What sort of training is required to do the job? Which generic skills (e.g., strategic and leadership, environmental awareness, coordination/management/business, entrepreneurial, systems and risk analysis, innovation, interpersonal communication/negotiation, marketing, language, interdisciplinary, other) are much weaker than required for core occupations?

In general, has the training response to the RE sector's skill needs been sufficient to meet demand or not? If insufficient, in what ways? Do you see a gap growing? What are the key occupations that will be most in demand in RE over the next 5 years? What are the sources of training and are they adequate? (e.g., in-house, outside…)

Are there impediments to hiring skilled workers from other countries? To what extent does skills availability and training infrastructures impact cross-border renewable energy investment decisions? How do RE businesses operating internationally respond to local skills shortages or deficiencies, at the time of the initial investment and subsequently. What strategies do they use? How much international mobility do you see among people working in the renewable energy sector? Why is this? In what occupations and types of job do you see significant mobility? Why is this? In your sector and country, to what extent is hiring workers from among host communities and/or indigenous peoples an issue? For what types of jobs are they typically recruited, and how are they trained?

IGA Education Committee

Appendix 3

University Roster – 2 October 2010

Country	City	University	Institute / Laboratory	Course / Programme	Grade
Germany	Bochum	Applied Science		Bauingenieurwesen / Geothermische Energiesysteme	Master
				Bauingenieurwesen	Bachelor
	Freiburg	Albert-Ludwigs-Universität		Hydrogeologie und Geothermie	Master
				Renewable Energy Management	Master
	Aachen	RWTH		Angewandte Geowissenschaften	Bachelor, Master
				Georessourcenmanagement	Bachelor, Master
				Applied Geophysics	Master
	Biberach	Hochschule		Gebäudeklimatik	Master
				Energiesysteme	Bachelor
	Darmstadt	TU		Angewandte Geowissenschaften	Bachelor
	Freiberg	TU Bergakademie			
	Karlsruhe	Universität		Angewandte Geowissenschaften	Bachelor

Country	City	University	Institute / Laboratory	Course / Programme	Grade
Germany	München	Ludwig-Maximilians-Universität		Geowissenschaften	Bachelor
				Geophysics	Master
USA	Stanford	Stanford University		Energy Resources Engineering	Master, PhD
	Ithaca	Cornell University	Centre for a Sustainable Future		
	Reno	University of Nevada, Reno	National Geothermal Training Institute		Certificate program
			Department of Geological Sciences		Master, PhD
			Great Basin Centre for Geothermal Energy		Master, PhD funding
	Reno	Truckee Meadows Community College	Renewable Energy; Applied Industrial Technology		Associate of Applied Science
	Klamath Falls	Oregon Institute of Technology		Renewable Energy Engineering	Bachelor
	Portland	Oregon Institute of Technology		Renewable Energy Engineering	Bachelor

Country	City	University	Institute / Laboratory	Course / Programme	Grade
Iceland	Reykjavik	University of Iceland	School of Engineering and Natural Sciences		BSc, MSc, PhD.
	Reykjavik	Reykjavik University	School of Science and Engineering Mechanical and Energy Engineering BSc		Bachelor
	Reykjavik	REYST (University of Iceland and Reykjavik University)		Well logging and Geothermal and groundwater reservoir management	Master
				Measurements and system analysis in geothermal power plants	Master
	Akureyri	RES School for Renewable Energy Science		Renewable Energy Science / Geothermal Energy	Master
	Asbru	Keilir		Renewable Energy Technology	Bachelor
	Reykjavik	The United Nations University Geothermal Training Programme		6 months Geothermal Training Programme (April-October) divided into three phases; the introductory lectures, the specialized training and the research project.	UNU certificate, diploma The programme can be extended to a MSc and PhD in cooperation between the UNU-GTP and the University of Iceland

Country	City	University	Institute / Laboratory	Course / Programme	Grade
New Zealand	Auckland	University of Auckland	Faculty of Engineering, Dept of Engineering Science	Post Graduate Diploma in Geothermal Energy Technology	PGCertGeotherm, Master, PhD
			Faculty of Science	Faculty researchers within the School of Environment, Faculty of Science, teach and research on all aspects of geothermal geology and geochemistry. Teaching contributions are also made to the PGCertGeothermTech course hosted by the Faculty of Engineering. Geothermal geochemistry is available from the bachelors level to doctorate; geothermal geology is available for graduate study and research.	B.Sc., B.Sc.(Hons), Master, PGDipsci, PhD
			Faculty of Engineering (jointly with Faculty of Science and Faculty of Business and Economics)	The Master of Energy degree will be offered from 2011. This is a professional-level degree that covers aspects of science, engineering, and energy economics related to renewable energy including a specialization in geothermal; other specializations include wind energy and petroleum. A four-year bachelor's degree is required for entry (or a three year bachelor's degree with a PGDip or equivalent). Students will do specialized training a research project.	M.Energy (from 2011 onwards)
			Faculty of Engineering		

Country	City	University	Institute / Laboratory	Course / Programme	Grade
New Zealand	Wellington	Victoria University	School of Geography, Environment and Earth Sciences	Research topics in the volcanology/geochemistry/geothermal/petrology group	Master, PhD
Japan	Kumamoto	Kumamoto University	Department of Life and Environmental Sciences, Graduate School of Science and Technology		Master, PhD
	Fukuoka	Kyushu University	Graduate School of Engineering	International Special Course on Environmental Systems Engineering	PhD
			Department of Earth Resources Engineering, Graduate School of Engineering		Master, PhD
			Department of Earth and Planetary Sciences, Graduate School of Sciences		Master, PhD
			Department of Chemistry, Graduate School of Sciences		Master, PhD

Country	City	University	Institute / Laboratory	Course / Programme	Grade
Japan	Fukuoka	Kyushu University	Department of International Societies and Cultures, Graduate School of Social and Cultural Studies		Master, PhD
			Department of Earth Resources, Marine and Civil Engineering, School of Engineering	Earth System Engineering Course	Bachelor
			Department of Earth and Planetary Sciences, School of Sciences		Bachelor
			Department of Chemistry, School of Sciences		Bachelor
	Beppu	Kyoto University		Geochemistry	PhD
	Kanazawa	Kanazawa University		Heat and Mass Transfer in Porous Media/Ground Water Flow	Master, PhD
	Sendai	Tohoku University		Geosystem and Energy Sciences	Master, PhD

Country	City	University	Institute / Laboratory	Course / Programme	Grade
Japan	Akita	Akita University	Graduate School of Engineering and Resource Science		Master, PhD
	Yurihonjo	Akita Prefectural University	Faculty of Systems Science and Technology		Bachelor, Master
	Muroran	Muroran Institute of Technology	Division of Information and Electronic Engineering		Master, PhD
Mexico	Ensenada	CICESE (Centro de Investigación Científica y de Educación Superior de Ensenada)		Earth Sciences, with specialty in geophysical exploration and monitoring of geothermal resources. In Spanish. Ciencias de la Tierra, especialidad en exploración y monitoreo de recursos geotérmicos.	Master, PhD
	Cuernavaca	IIE (Instituto de Investigaciones Electricas)		Chemical and Isotopíc Geochemistry, Geothermal Reservoir Engineering. In Spanish. Geoquímica Química e Isotópica; Ingeniería de Yacimientos Geotérmicos.	IIE certificate, diploma
Poland	Krakow	AGH - University of Science and Technology		Environmental Engineering – Renewable Energy Sources (incl. Geothermal energy)	Bachelor, Master, PhD (studies in Polish)

Country	City	University	Institute / Laboratory	Course / Programme	Grade
Philippines	Legaspi	Bicol University		Geothermal Engineering (Ladderized curriculum under BSME)	BSc
	Manila	Mapua Institute of Technology		Geology	BSc, MSc
		Adamson University		Geology	BSc
	Quezon City	University of the Philippines_ NIGS		Geology	BSc, MSc, PhD
	Dumaguete City	Negros Oriental State University		Geothermal Engineering & Geology	BSc
Macedonia	Skopje	St Ciril and Metodij	Faculty of Mechanical Engineering		BSc, MSc, PhD
			Faculty of Power Engineering		BSc, MSc, PhD
			Faculty of Natural Sciences – Physics		BSc, MSc, PhD
	Bitola	St Kliment Ohridski	Faculty of Technical Sciences		BSc, MSc, PhD

Country	City	University	Institute / Laboratory	Course / Programme	Grade
Switzerland	Neuchâtel	University of Neuchâtel	Institute of Hydrogeology and Geothermics (CHYN)	Master in hydrogeology and geothemics, in cooperation with the Swiss Federal Institute of Technology (EPF-L) and the University of Lausanne – In French	MSc, PhD
Romania	Oradea	Universitatea din Oradea (University of Oradea)	Renewable Energies	Master – In Romanian	Master
Hungary	Miskolc	University of Miskolc Faculty of Earth Science		Post Graduate Diploma in Geothermal Energy Technology	PGCertGeotherm
				Petroleum and Natural Gas Institute	BSc, MSc, PhD
Indonesia	Yogyakarta	Gadjah Mada University	Faculty of Engineering	Geological Engineering with major in Energy Resources (special papers and thesis on Geothermal Geosciences)	Bachelor, Master, PhD
				Mechanical Engineering with major in Energy Conversion (special papers and thesis on Geothermal Technology)	Bachelor, Master, PhD
				Short courses on Geothermal Geosciences and Technology	Non-degree
			Faculty of Mathematics and Natural Sciences	Geophysics Study Program with major in Geothermal Geophysics	Bachelor, Master, PhD

Skills and Occupational Needs in Renewable Energy

The renewable energy sector is growing fast: about half of the new electricity-generating capacity added globally in 2008 and 2009 came from renewable energy additions. Renewable energy is expected to generate more jobs over the coming years in the energy sector as a whole. Employment in fossil fuel, however, will drop as energy production turns greener. Fast deployment of new capacity at country or regional levels has led to skills shortages in technical occupations such as solar installers and electrical engineers, but also in more general occupations, such as sales and finance specialists, inspectors, auditors and lawyers. An efficient training system for renewable energy must be integrated within overall policies to support the growth of the sector. It must also involve social partners in the design and delivery of training, retraining of workers and draw from a combination of practical and theoretical knowledge.

The study *Skills and Occupational Needs in Renewable Energy* brings together the findings from 33 countries. It arises from a joint management agreement between the European Commission and the ILO on *Knowledge sharing in early identification of skill needs*. Two additional reports resulted from this cooperation: *Skills and Occupational Needs in Green Building* and *Comparative Analysis of Methods of Identification of Skill Needs on the Labour Market in Transition to the Low Carbon Economy.*

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