The Socio-economic Benefits of Solar and Wind Energy

CLEAN ENERGY
MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

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About IRENA

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

About CEM

The Clean Energy Ministerial (CEM) is a high-level global forum to promote policies and programs that advance clean energy technology, to share lessons learned and best practices, and to encourage the transition to a global clean energy economy. Initiatives are based on areas of common interest among participating governments and other stakeholders.

Acknowledgements

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

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Foreword

Renewable energy technologies have experienced rapid deployment over the past few years, mainly driven by the ambition to improve energy security, enhance energy access and mitigate climate change. Many countries are now exploring ways to stimulate social and economic growth through the development of the renewable energy sector. Investment in renewable energy can generate new sources of growth, increase income, improve trade balances, contribute to industrial development and create jobs. While such socio-economic benefits are increasingly gaining prominence in the global renewable energy debate, specific analytical work and empirical evidence on this important subject remain relatively limited.

The Socio-economic Benefits of Solar and Wind: an econValue report bridges the knowledge gap with a holistic analysis of the environmental, social and economic value created from large-scale solar and wind energy deployment. In doing so, it offers a new conceptual framework in support of ongoing analytical work conducted by IRENA and other partners in the Clean Energy Ministerial with a view to reinforcing the economic and business case for renewable energy.

The report highlights the significant potential for value creation along the different segments of the value chain for solar and wind technologies, including project planning, manufacturing, installation, grid connection, operation and maintenance and decommissioning. Additional opportunities for value creation arise from supporting activities, such as education and training, financing and policy making. To benefit fully from the socio-economic impacts of renewable energy, the right mix of cross-sectoral policies, covering deployment and industrial policies, is needed. Building a domestic renewable energy industry requires stimulating investments, strengthening firm-level capabilities, promoting education and training, and encouraging research and innovation.

The country case studies presented here demonstrate that there is no one-size-fits-all policy solution to maximise value creation, and that successful policy making requires close coordination and engagement of diverse stakeholders. The report underlines the need for sound quantitative analysis of expected socio-economic effects in order to enable informed policy choices. It presents different tools available for such estimations, gives guidance for selecting the most appropriate among them, and emphasises the importance of comprehensive data for such analysis.

I am confident that the findings in this study will further strengthen the business case for renewables, as well as provide a valuable reference point in discussions on value-creation opportunities. The recommendations of the report can contribute to policy design and implementation that maximise socio-economic benefits from the transition to a sustainable energy future.

Adnan Z. Amin
Director - General of International Renewable Energy Agency

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Acronyms

AMDI	Agence Marocaine de Développement des Investissements (Moroccan Investment Development Agency)
ANPME	Agence Nationale pour la Promotion de la Petite et Moyenne Entreprise (Moroccan Agency for the Promotion of Small and Medium-size Entreprises)
BIPV	Building-Integrated Solar PV
BNDES	Banco Nacional de Desenvolvimento Economico e Social (Brazilian Development Bank)
CaDRE	Capacity Development Needs Diagnostics for Renewable Energy
CSP	Concentrated solar power
E&E	Electrical and Electronics
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EF	Employment factor
EU	European Union
EUR	Euro
FIPA	Tunisian Foreign Investment Promotion Agency
FiT	Feed-in tariff
FTE	Full-time equivalent
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation)
GTAP	Global Trade Analysis Project
GW	Gigawatt
GWEC	Global Wind Energy Council
GWh	Gigawatt-hour
FDI	Foreign direct investment

IDAE	Instituto para la Diversificación y Ahorro de la Energía (Institute for the Diversification and Saving of Energy)
IEA	International Energy Agency
ILO	International Labour Organization
I-O	Input-Output
IRENA	International Renewable Energy Agency
JEDI	Jobs Economic Development Impacts
LCR	Local content requirement
MENA	Middle East and North Africa
MNRE	Ministry of New and Renewable Energy
MW	Megawatt
MWh	Megawatt-hour
NSDP	National Suppliers Development Programme
NSM	National Solar Mission
OECD	Organisation for Economic Co-operation and Development
O&M	Operations and maintenance
PPP	Public-private partnerships
PV	Photovoltaic
R&D	Research and development
RE	Renewable energy
RET	Renewable energy technology
RPS	Renewable portfolio standard
SAM	Social Accounting Matrices
SME	Small and medium-sized enterprise
SWEG	Sewedy Wind Energy
USD	U.S. dollar

Summary for policy makers

Unveiling the value creation potential of renewable energy

Socio-economic benefits are gaining prominence as a key driver for renewable energy deployment. With many economies faced with low growth, policy makers see potential for increased income, improved trade balance, contribution to industrial development and job creation. However, analytical work and empirical evidence on these topics remain relatively limited.

In an effort to contribute to this field of knowledge, this report presents a conceptual framework for analysing the socio-economic effects of large-scale renewable energy deployment. The proposed framework is adapted from the existing literature and aims to understand the social, economic and environmental value that can be created from renewables. For analytical purposes, it classifies socio-economic effects as: macroeconomic, distributional, energy system-related and other cross-sectoral (additional). This analysis focuses on one category of effects, namely macroeconomic, within which four variables are addressed – value added, gross domestic product, welfare and employment.

CONCEPTUAL FRAMEWORK FOR ANALYSING THE SOCIO-ECONOMIC EFFECTS OF LARGE-SCALE RENEWABLE ENERGY DEPLOYMENT
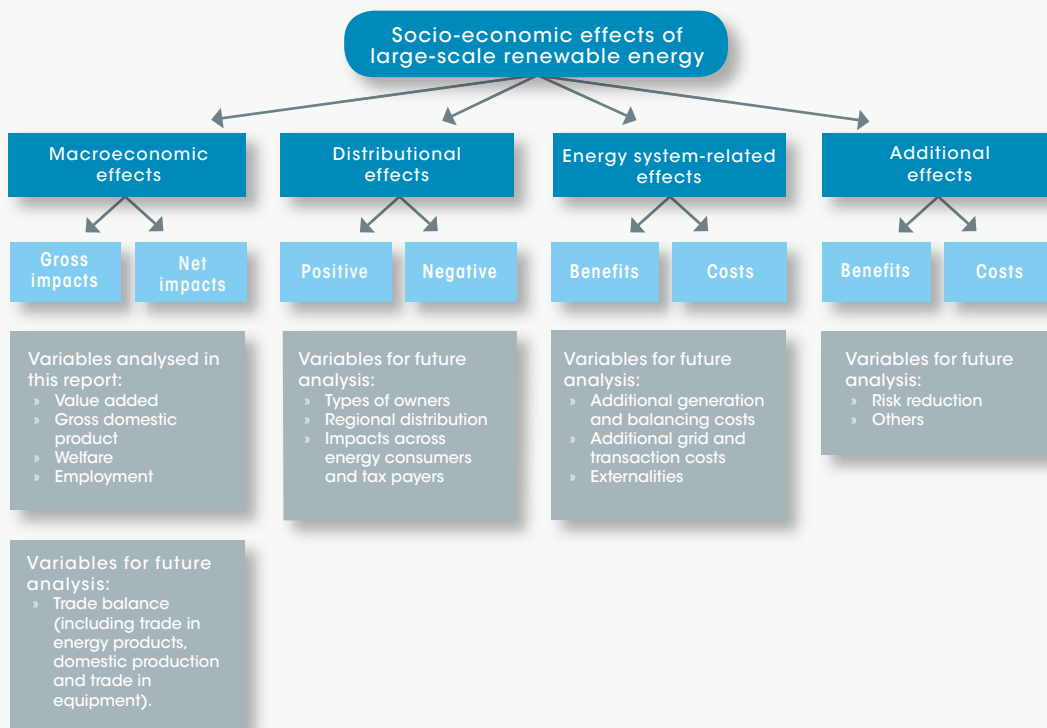
Source: Adapted from Fraunhofer ISI et al., 2012; BMU, 2013a

Socio-economic effects can be measured along the different segments of the value chain, including project planning, manufacturing, installation, grid connection, operation and maintenance and decommissioning. Further opportunities for value creation exist in the supporting processes such as policy-making, financial services, education, research and development and consulting.

TYPICAL SEGMENTS OF THE RENEWABLE ENERGY VALUE CHAIN

| Segment of Value Chain | Project Planning | Manufacturing | Installation | Grid Connnection | Operation and Maintenance | De-commissioning |

Supporting Processes	Policy Making
	Financial Services
	Education
	Research & Development
	Consulting
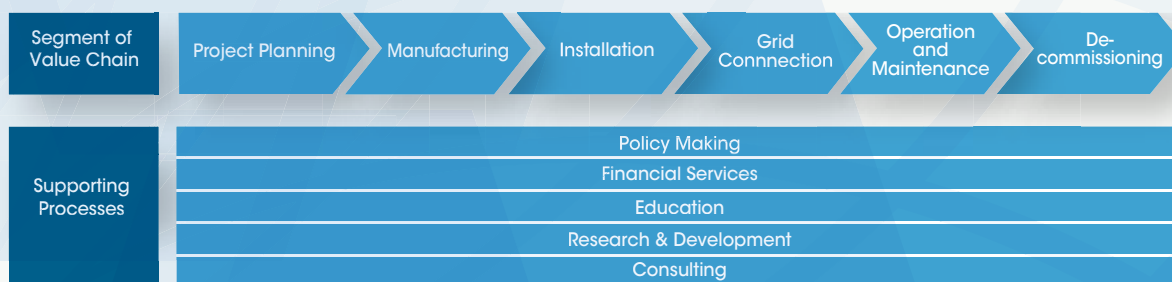
Source: Adapted from MWGSW, 2011..

In the **planning** segment, value is mostly created by the engagement of specialised individuals and companies to conduct resource assessments, feasibility studies, project designs, legal activities, etc. While planning for wind energy projects is usually undertaken by developers, there is potential for a greater number of companies or consultancies to be involved for concentrated solar power plants, which includes many steps, such as basic scoping, concept engineering and geographical determination.

Value can be created in each step of **manufacturing**, from the sourcing of raw materials, to component manufacturing and assembly. For wind technology, value can be created from the manufacturing of sub-components such as rotorblades, towers and nacelles. For photovoltaic plants, value is created in the different steps from the production of silicon to manufacturing modules and in the additional components such as inverters, mounting systems, combiner boxes, etc. Manufacturing concentrated solar power plant components, such as mirrors, receivers and power blocks, involves different industry sectors, with varying potential for local value creation. Concentrated solar power technology components such as bent glass for the parabolic mirror need to be produced by highly specialised manufacturers. Hence, the potential for value creation in this sector is not applicable to all markets and differs according to the concentrated solar power technology chosen. For instance, a large portion of the components of a central tower can be manufactured locally (Morocco), compared to a parabolic trough which is highly specialised. The presence of other industries with similar processes can facilitate the development of a local solar and wind industry; the steel or the automotive industry for wind, semi-conductor for photovoltaic, glass for concentrated solar power, etc.

The value created in the **installation** phase arises mostly from labour-intensive activities involving civil engineering infrastructure works and assembling of wind or solar plants. These are typically carried out by local engineering, procurement and construction companies, thereby creating value domestically. However, if the equipment is imported, manufacturers can be responsible for installation activities. In the specific case of the wind industry, growing deployment can lead to the development of a specialised segment within the local logistical services industry for transporting wind turbine components, thereby creating value.

The **grid connection** stage involves highly skilled grid operators responsible for integrating renewable generation as well as local companies to undertake infrastructure development necessary to facilitate grid connection. For instance, grid connection of wind farms consists of cabling work within the wind farm itself (between turbines) as well as connecting the farm to the grid. Moreover, development and upgrading of grid infrastructure to integrate renewables can contribute to broader value creation in terms of improving the reliability of electricity supply and facilitating energy access.

Operation and maintenance is a long-term activity that offers opportunities for domestic value creation, regardless of a country's local renewable energy technology manufacturing capabilities. Wind and solar plants require personnel for operation and maintenance activities such as regular plant monitoring, equipment inspections and repair services, thus creating long-term jobs.

Decommissioning of renewable energy plants at the end of their lifespan can comprise recycling as well as disposal or reselling of components. Value is created in related recycling industries, demolition activities, and refurbishing of equipment for sale to other markets. This phase will increase in importance as renewable energy plants reach the end of their lifespan.

The potential for creating value domestically depends to a large extent on the level of development of a country's renewable energy sector. Countries at the beginning of renewable energy development have a medium to high potential for domestic value creation in activities such as operation and maintenance and grid connection. With the development of a local industry, many more opportunities for domestic value creation arise along all segments of the value chain and along supporting services such as research and development and consulting.

Potential domestic value creation depending on the stage of industry development

POTENTIAL FOR DOMESTIC VALUE CREATION	STAGE OF DEVELOPMENT		
	BEGINNING OF WIND & SOLAR ENERGY DEVELOPMENT	**FIRST PROJECTS REALISED, LOCAL INDUSTRIES SUITABLE FOR PARTICIPATING**	**MANY PROJECTS REALISED, NATIONAL WIND/SOLAR INDUSTRY DEVELOPING**
Lifecycle phase			
Project planning	Low	Medium	High
Manufacturing	Low	Medium	Medium/High
Installation	Low	Medium	High
Grid connection	High	High	High
Operation & maintenance	Medium	High	High
Decommissioning	Low	Low	Medium
Supporting processes			
Policy-making	High	High	High
Financial services	Low/Medium	Medium	High
Education and training	Low/Medium	Medium	Medium/High
Research & development	Low	Low/Medium	Medium
Consulting	Low	Low	Medium

Source: based on MWGSW, 2011

Policy instruments to maximise value creation

A broad range of cross-cutting policy instruments influence value creation from the deployment of large-scale solar and wind energy. These policies can stimulate deployment and aim at building a domestic industry by encouraging investment and technology transfer, strengthening firm-level capabilities, promoting education and training, as well as research and innovation. Maximising value creation requires the right policy mix, which is cross-cutting and tailored to country-specific conditions. Turkey is an interesting case in point in the policy mix it has implemented. The mix includes deployment policies (feed-in tariff), local content requirements and strengthening firm-level capabilities (through industrial upgrading programmes and the promotion of joint ventures) that work together to maximise local value creation. Close coordination and engagement of stakeholders from different sectors is key for the success of both policy-making and policy implementation.

Deployment policies enable investment in the sector and impact value creation with varying intensity along the different segments of the value chain. Such policies are most successful when they foster the stable and long-term market development of solar and wind energy technologies while, at the same time, adapting to dynamic technological and market developments. The impact on value creation depends on the type and design of the policy. For instance, some deployment policies, such as tax reductions, can enable value creation in installation, operation and maintenance while others, such as auctions, can also create value in manufacturing, especially when they are designed to include local content requirements.

Local content requirements can be used to support the development of a nascent domestic industry, create employment and promote technology transfer. Specific socio-economic benefits in line with national priorities can be targeted through the design of local content requirements. In South Africa, for instance, the renewable energy auction scheme was designed to promote job creation, enterprise development and empowerment of marginalised social groups and local communities. Generally, it is essential to consider existing areas of expertise in the design of local content requirements and link them closely to a learning-by-doing process. To ensure the full-fledged development of an infant industry, local content requirement should be time-bound and accompanied by measures that facilitate financing of the industry, the creation of a strong domestic supply chain and a skilled workforce.

International financial cooperation is increasingly relevant for value creation in developing solar and wind energy projects and manufacturing facilities. Investment promotion mechanisms can be adopted to overcome existing financing barriers and to attract investors, both domestic and foreign. For the latter, these mechanisms can facilitate investment in the form of official development aid or through foreign direct investment. Aside from employment creation and the development of new sectors, foreign direct investment may also contribute to technology transfer through business linkages such as joint ventures, partnerships and consortiums or research collaboration. For instance, the El-Sewedy Group, with financial support from the European Union, began exploring potential avenues for entry into the renewable energy sector in Egypt. This resulted in the creation of the Sewedy Wind Energy Group, a tower manufacturing facility in Cairo, through a joint venture agreement with the German wind tower manufacturer SIAG Schaaf Industries AG. The group also acquired a stake in the Spanish company M.Torres Olvega's as a way of obtaining the know-how to domestically manufacture wind turbines, thereby also contributing to the development of the domestic wind energy industry.

Enhancing domestic firm-level capabilities can boost the development of local industries. Cross-cutting policy interventions, such as industrial upgrading programmes, supplier development programmes and the development of industrial clusters, can contribute to increased competitiveness. In Morocco, for instance, industrial upgrading programmes have been established with the overall objective of increasing exports and creating jobs. The programmes enable the modernisation of small and medium enterprises by providing financial support, as well as consulting services on strategy, marketing and training aspects. This is intended to strengthen firms' capabilities by enhancing their business skills related to the production process, procurement, design and research and development. Thus far, the programmes have benefited over 3 000 companies.

Research and innovation in solar and wind energy technologies can also contribute to value creation. The value created is the knowledge that can lead to technological breakthroughs, improvements of products and services, and increasing the applicability of technologies to local conditions. These can accelerate deployment and reduce costs, thereby supporting further value creation. It should be noted, however, that increased labour productivity and mechanisation can have a negative net effect on local value creation. In general, close coordination between industry, consumers and research institutions is necessary to maximise value creation from research and innovation. For example, the Fraunhofer Institute for Solar Energy Systems has achieved several successes in solar research (*e.g.*, high efficiency values for cells or inverters, first quintuple-junction solar cell, etc.) and currently employs about 1 300 researchers. Since its foundation, several spin-offs have been established, such as production of concentrators and water treatment with solar energy.

Education and training in renewable energy generate value by providing the skills necessary to support the development of the industry. Policies and measures that target the development of skills, including financing for renewable energy education and training, the inclusion of renewable energy in educational programmes and strategic planning to meet skill needs are key for creating value. Adequate planning for the education sector that integrates education and training policies within national renewable energy strategies has proven to be essential. Malaysia's National Renewable Energy Policy and Action Plan, for example, includes support policies for education and training that incorporate renewable energy into technical and tertiary curricula, develop training institutes and centres of excellence and provide dedicated financial support. These policies should be accompanied by continuous collaboration between industry and policy makers from the energy and education sectors.

There is no one-size-fits-all policy solution to maximise value creation – the right policy mix requires close coordination and engagement of key stakeholders involved in the design and implementation of relevant policies. Factors that should be considered while formulating long-term strategies for the solar and wind energy sectors include the stage of renewable energy and industrial development; the general business environment and country competitiveness as well as the dynamics of regional and global markets for wind and solar energy components and services.

Methods and tools to assess value creation

Sound quantitative analysis of the expected socio-economic effects of solar and wind energy deployment is essential to enable informed policy choices. Such an analysis helps to monitor policy effectiveness and to communicate benefits to the public at large with reliable facts and figures. The implementation of policies without analysing their full economic effects can pose significant risks on countries' medium-term economic sustainability and associated policy stability.

The quantitative assessment of the socio-economic impacts of solar and wind energy deployment is a complex but valuable endeavour. The required information is seldom captured in standard national statistics due to the cross-cutting and relatively new nature of the sector. Countries need to provide financial resources for data collection and institutional capacities to handle the data.

The selection of the most appropriate tool for the assessment includes several steps. The first step is defining the variables to be assessed (employment, GDP, etc.) along with their characteristics (gross or net; regional, national or sub-national; obtained by optimisation or by simulation, etc.). The second step is to select a tool that generates the required outputs. The third step is to assess if the necessary inputs are available in terms of resources (expertise, time and money) and data.

KEY RECOMMENDATIONS

The findings of this report indicate that in designing and implementing policies to maximise value creation, policy-makers may consider:

Analysing socio-economic value creation of renewable energy

» Assessing the impact of solar and wind energy deployment on value creation is critical for making informed policy decisions. Value creation can be measured by macroeconomic variables such as value added, gross domestic product, welfare and employment. Given the cross-sectoral nature of the renewable energy industry, the analysis should be conducted along the different segments of the value chain.

» Policy makers should pursue value creation depending on local conditions and the stage of renewable energy deployment. In each segment of the value chain of wind and solar energy projects (including project planning, manufacturing, installation, grid connection, operation and maintenance and decommissioning) value

is created by different industries in the delivery of the respective sub-products and sub-processes. Countries at early stages of development have higher potential for value creation in activities such as operation and maintenance, or grid connection. With further developments, many opportunities for domestic value creation arise in other segments of the value chain.

Adopting the right policy mix to maximise value creation

» Policies that stimulate deployment and aim at building a domestic industry by encouraging investment and technology transfer, strengthening capabilities, promoting education and training, as well as research and innovation greatly affect value creation. It is, therefore, important that policy makers develop an appropriate mix of policies tailored to country conditions and priorities.

» Close coordination and engagement of stakeholders from different sectors is key for the success of both policy-making and policy implementation. Policies should be designed as part of a holistic framework that is consistent with and supports a well-defined national strategy. In addition, a predictable long-term policy framework for renewable energy market development is necessary to ensure stability in the value generated through deployment.

» Policy choices aimed at developing a domestic industry need to be tailored to countries' particular strengths and weaknesses. For instance, the design of local content requirements should consider existing areas of expertise along the different segments of the value chain and be directed at those with the highest development potential. Such policies should be accompanied by measures to enhance firm-level capabilities, develop relevant skills, and advance research and development.

» In enhancing firm-level capabilities to increase the level of competitiveness of domestic firms, policy-makers may consider measures such as industrial upgrading programmes, supplier development programmes, and cluster development.

» In developing the relevant skills, policy-making should include the identification, anticipation and provision of adequate education and training in the sector. Including renewable energy subjects in existing and new educational programmes should be encouraged, and financial support to relevant institutions should be provided. Cooperation and cohesive action between the private and public sectors, industry associations and international organisations can help ensure the success of such policies.

» Policy makers may consider promoting research and development activities that can help address challenges faced by local industries and facilitate spin-off products to maximise value creation. To create an enabling environment for research and innovation, supporting measures can include funding, building competence and human capital, facilitating knowledge diffusion and developing infrastructure.

Gathering data and estimating value creation

» Many tools can be used to estimate the socio-economic impacts of solar and wind energy deployment, with different scope and capabilities. The most appropriate tool should be selected based on the specific socio-economic impact to be quantified and on human and financial resources available.

» Governments need to systematically collect data required for a rigorous estimation of the value creation impacts of renewable energy deployment. Data availability can be improved by adding targeted questions to industry and statistical surveys, or by developing case studies. The data should be well defined and collected over a long time series, as well as comply with international reporting standards to ensure comparability among countries.

About the report

Purpose. This report presents a comprehensive overview of the opportunities for value creation from the deployment of large-scale solar and wind energy technologies. It contributes to bridging the existing knowledge gap on the topic and gives policy makers and other stakeholders evidence on economic value creation from the accelerated deployment. The report analyses various policy instruments that stimulate value creation and draws on the experience of developed and emerging countries to provide recommendations on how value creation can be maximised. Guidance is provided on the selection of the appropriate tools to measure the socio-economic impact.

Target audience. The findings of this report can support policy makers in maximising the value created from developing a domestic renewable energy sector, specifically for solar and wind technologies. It is also targeted towards institutions that focus on related social and economic issues. The analysis and insights presented in the report are relevant also to a broader audience seeking general information on the socio-economic aspects of renewable energy.

Information sources. The report compiles information from a wide variety of publicly available reports, studies and databases. The underlying literature review includes publications by government ministries and international agencies, industry associations, non-governmental organisations, consultancies and academic institutions. It includes articles published in both printed form and online renewable energy journals. Country case studies were undertaken by IRENA and provide empirical evidence to support the analysis. Chapter 2 of the report draws on a study conducted by the IEA Implementing Agreement for Renewable Energy Technology Deployment (IEA-RETD) on *Policy Instruments to Support RE Industrial Value Chain Development.*

Technologies covered. This study focuses on large-scale deployment of solar (photovoltaic and concentrated solar power) and wind energy technologies for electricity generation. However, many aspects discussed in this report may be equally relevant for other renewable energy technologies.

Analytical framework. This report provides a comprehensive conceptual framework which classifies the socio-economic effects of renewable energy deployment into four main categories to allow for their systematic quantification: macroeconomic, distributional, energy sector and other cross-sectoral (additional) effects. The conceptual framework provides the basis for analysing value creation along the value chain of solar and wind energy technologies including project planning, manufacturing, installation, operation and maintenance and decommissioning, as well as supporting services (education, research and development, financing and consulting).

Variables covered. This report focuses on the macroeconomic effects, specifically value added, gross domestic product, employment and welfare to measure value creation of renewable energy. The other aspects of value creation named above are also addressed, but are not the central focus of this report. They will be analysed more thoroughly in future IRENA activities.

Limitations. Given the scope of the report, the analysis focuses on electricity-related large-scale installations of solar and wind energy technologies. The conceptual framework is based on existing literature and on-going research, and will be further refined. The analysis specifically addresses four macroeconomic variables given their relevance.

Structure. The report includes three chapters:

Chapter 1 presents the conceptual framework for analysing value creation of renewable energy. It identifies key variables and analyses value creation effects along the solar and wind energy value chains. The chapter discusses key aspects of value creation opportunities and how they affect economic growth and employment.

Chapter 2 analyses policies that stimulate deployment and aim at building a domestic industry by encouraging investment and technology transfer, strengthening firm-level capabilities, promoting education and training, as well as research and innovation. The chapter contains policy recommendations on how to maximise value creation from the deployment of solar and wind energy.

Chapter 3 presents an overview of the different methods that can be used to assess socio-economic impacts of renewable energy. It gives guidance on the selection of the most appropriate tool to assess socio-economic impacts based on human and financial resources available.

1 Analysing Socio-economic Value Creation

Project Planning

Manufacturing

Construction & Installation

Grid Connection

O&M

Decommissioning

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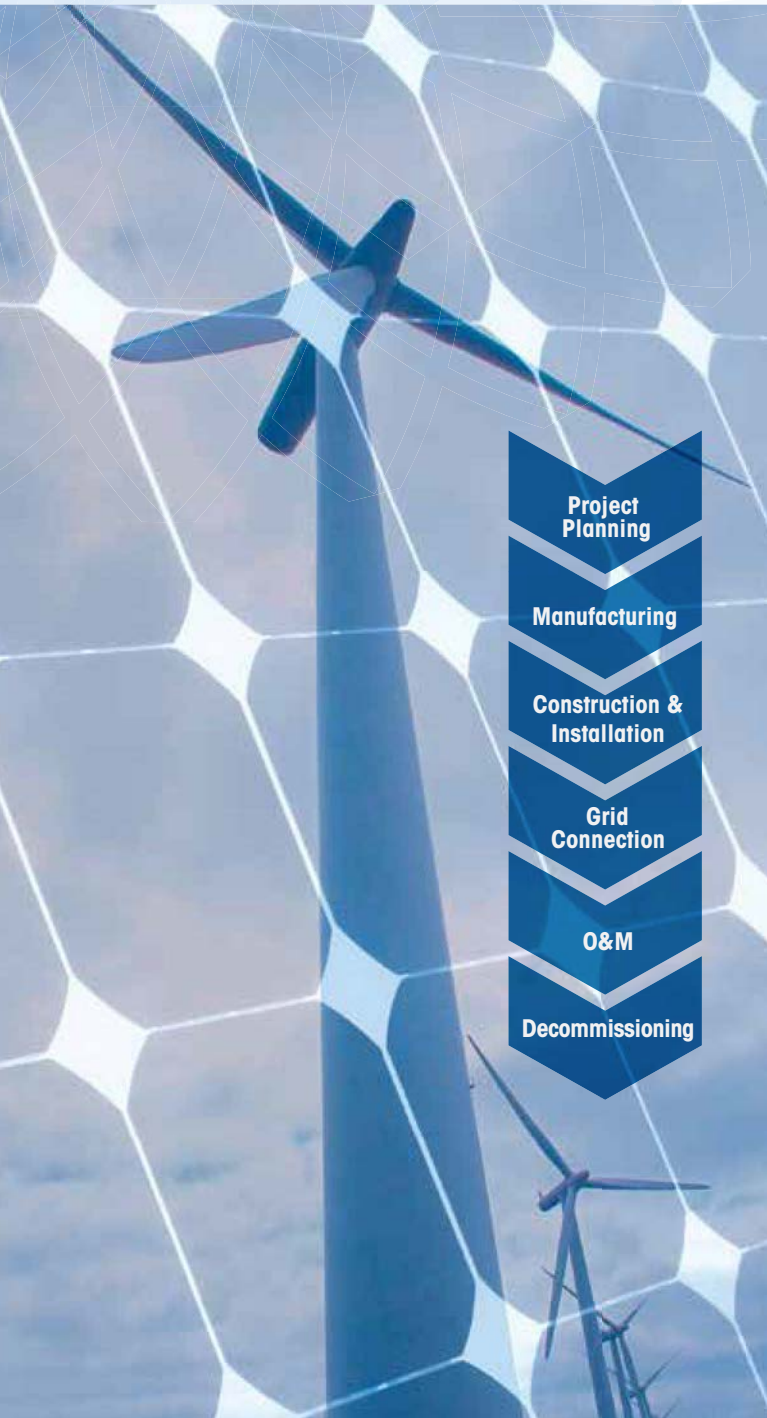
Recent decades have seen an increase in the large-scale deployment of renewable energy technologies (RET). Key drivers for this expansion have been energy security, environmental concerns and energy access. With many economies faced with low growth, socio-economic benefits have come at the forefront of the policy-making debate and strategic choices made by countries. Also, many countries still recovering from economic crisis see immense opportunities in the development of a renewable energy sector, with a potential to increase income, improve trade balance, contribute to industrial development and create jobs. IRENA's recent report on *Renewable Energy and Jobs – Annual Review 2014,* estimates that renewable energy jobs reached 6.5 million in 2013 (IRENA, 2014a).

Generally, however, analytical work and empirical evidence on this important subject remain relatively limited. In particular, it is essential to understand how economic value of renewable energy deployment can be measured and where value can be created within different segments of the solar and wind energy value chains. This chapter introduces a conceptual framework for quantifying the socio-economic effects of renewable energy deployment. It examines some of the variables that can be used to assess the potential value creation. Finally, it shows how value can be created in different segments of the value chain. Throughout the chapter, selected examples from country case studies are used to better illustrate some of the concepts.

Section 1.1 defines the concept of socio-economic value through a broad analytical framework, to examine the socio-economic effects (both costs and benefits) of renewable energy deployment (see Figure 1.1). The proposed framework identifies the broad categories under which the effects of renewable energy deployment can be classified. These are: i- macroeconomic

effects; ii- the distributional effects of changing ownership structures; iii- energy system-related effects; and iv- additional effects such as reduced risks.

Section 1.2 explores measures of value creation and some of the variables that can be used to measure it. Given the focus on economic value, the report elaborates on selected variables within the first category of effects, namely macroeconomic effects. In particular, four variables have been chosen – value added, gross domestic product (GDP), welfare[1] and employment (*variables analysed in this report*). The section then discusses opportunities for value creation along the value chain starting with a delimitation of what constitutes a renewable energy industry. It then analyses domestic value creation opportunities along the value chains of solar and wind energy as well as supporting services.

Section 1.3 briefly presents all the other variables (within the category of macroeconomic effects and other categories) that are not analysed in depth (*variables for future analysis*).

1.1 CONCEPTUAL FRAMEWORK FOR ANALYSIS

From a sustainable development perspective, the term **value creation** goes beyond the traditional economic definition, to include a vast array of socio-economic benefits to society. These include job creation, improved health and education, reduced poverty and reduced negative environmental impacts.

Conceptualising the socio-economic effects in a comprehensive and solid framework, where they can be quantified, aggregated and compared is a complex task, mostly addressed by cutting-edge research and analysis. Several of these effects may be hard to quantify (*e.g.* improved education) and their analysis remains therefore largely qualitative. Among those that can be quantified, some may not have the same units of measurement, and there is a risk of double counting or overlapping effects. Moreover, the same effects may be assigned different levels of priority according to national goals.

FIGURE 1.1 CONCEPTUAL FRAMEWORK FOR ANALYSING THE SOCIO-ECONOMIC EFFECTS OF LARGE-SCALE RENEWABLE ENERGY DEPLOYMENT
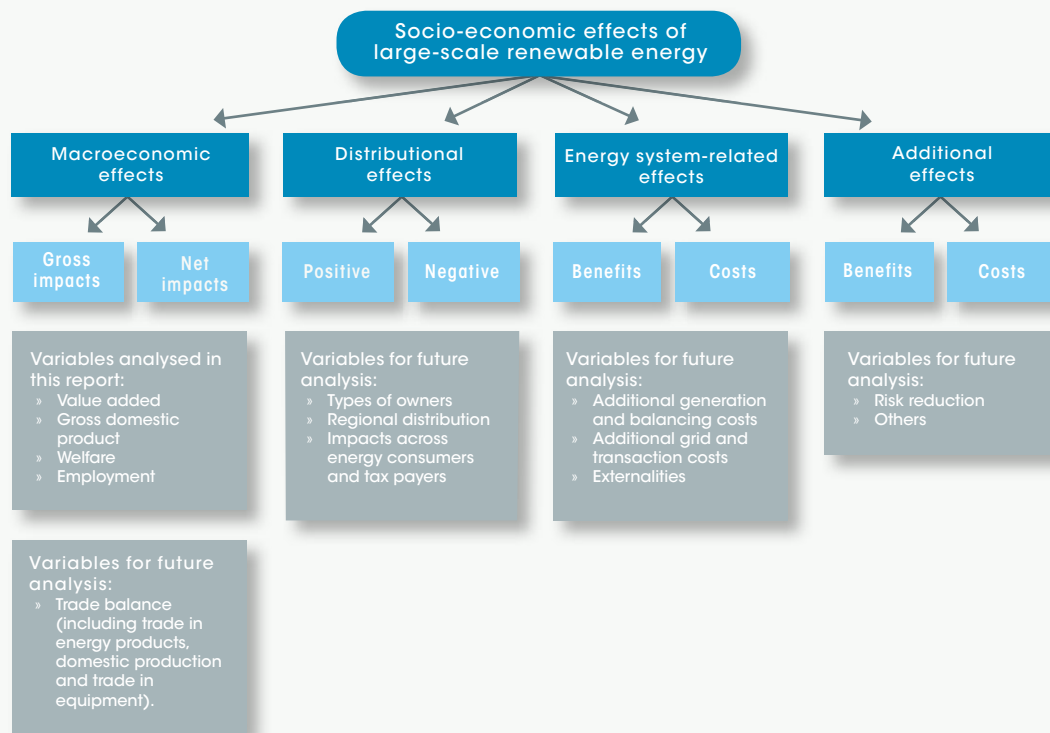
Note: *In this framework, the widely used concept of "energy security" or "security of supply" is divided between aspects related purely to the trade balance (classified within "macroeconomic effects") and those related to technical, geopolitical or financial risks (classified within "additional effects").*

Source: Adapted from Fraunhofer ISI et al. 2012; BMU 2013a

[1] *In this report, unless otherwise stated, the term "welfare" refers to what is considered welfare in conventional economics. It is measured as an aggregation of the utility that consumption or other issues (e.g., leisure) provide to a group of people. It is different from more comprehensive (and recent) measures of human welfare, some of them closely linked to sustainable development issues, such as the United Nation Development Programme's "Human Development Index" or the "Gross National Happiness Index" (these other welfare indicators are reviewed briefly later in the report).*

This chapter follows a conceptual framework similar to the one adopted by Fraunhofer ISI *et al.* (2012) and BMU (2013a), which was one of the first attempts to formulate these concepts from a policy-making perspective. In it, the socio-economic effects of renewable energy deployment are divided into four main categories[2]: macroeconomic effects, distributional effects, energy system-related effects and additional effects, as depicted in Figure 1.1.

Macroeconomic effects

Macroeconomic effects refer to the elements traditionally studied within the discipline of macroeconomics. These effects can be assessed either within the renewable energy and related sectors (gross impacts), or within the economy as a whole (net impacts) (see Chapter 3). The macroeconomic effects include the four key variables analysed in this report: value added, GDP, welfare and employment (see sub-section 1.2.1). Further macroeconomic variables that will be covered in future analyses are those associated with trade balance. In the case of renewable energy, it is related to issues such as the trade of energy products, trade of RET equipment, domestic production and other related goods and services (Section 1.3).

Distributional effects

Distributional effects refer to the allocation of effects (both benefits and costs) to different stakeholders within the energy sector. They can be fiscal but can also relate to other aspects such as the type of ownership structure (even if fiscal instruments traditionally have been used with distributional purposes). Distributional effects can occur: i- among stakeholders within the renewable energy sector itself (*e.g.*, among types of owners of renewable energy plants); ii- within the energy sector as a whole (*e.g.*, distributional effects between renewable and conventional energy sources and among different types of energy consumers); iii- throughout the economy at a municipal, sub-national, national, regional or even global level; iv- between different sets of agents (*e.g.*, households of different income levels, firms, governments); or v- more generally between different generations (*i.e.*, related to the intergenerational equity debate in the framework of sustainable development).

These distributional effects are positive for the beneficiaries and negative for those who have to bear the corresponding burden. They have not been analysed in this study, but could include the type of owners of renewable energy plants, regional distribution and effects across energy consumers and tax payers.

Energy system-related effects

Energy system-related effects of renewable energy deployment reflect the additional costs or benefits compared to an energy system without renewables. This category contains the benefits and costs (direct and indirect) of renewable energy deployment, including, the additional generation costs (*e.g.*, due to more frequent ramping, which implies more frequent maintenance), the additional balancing costs (*e.g.*, the need for backup capacity), the additional grid costs (*e.g.*, to accommodate the power generated in a newly developed offshore wind park), the additional transaction costs (*e.g.*, the costs of wind forecasting), the benefits of reduced energy losses (some of these effects can also be classified within trade balance issues) and the benefits of reduced negative environmental externalities[3].

Additional effects

Additional effects cover all remaining benefits and costs that may be associated with RET deployment. These effects are not less important than the previous ones, but because they can be classified in more than one category, they have been grouped into a separate one to minimise double counting. One of the main additional effects of large-scale renewable energy deployment is risk reduction. It includes: i- the mitigation of possible accidents associated with conventional energy sources (*e.g.* nuclear accidents, oil spills, etc.); ii- the lower technical risks associated with a more decentralised energy system; and iii- the reduction of geopolitical and financial risks associated with energy dependence in importing countries. The latter risks are usually referred to as "security of supply" or "energy security" in the literature. Since they include a "trade balance" effect, including them under "macroeconomic effects" would lead to double counting.

It should be noted that the conceptual framework presented here is not complete. However, it is a first step in providing a comprehensive classification of socio-economic effects of renewable energy deployment in a modern energy context. Value creation in the context of energy access follows a different coceptual framework which is discussed in Box 1.1.

[2]   The literature suggests that, in order to avoid double counting, aggregated costs and benefits should be compared only within the respective category. It remains a research objective for the future to further integrate those distinct categories within a more comprehensive macro assessment model which will allow for a broad societal cost-benefit analysis of renewable energy deployment, ideally adding up all effects into a single figure through some type of multi-criteria comparison. For the time being, keeping those categories separate is the common practice, as is done in the EU project "DiaCore" (www.diacore.eu).

1.2 MEASURING VALUE CREATION

When analysing the value creation of renewable energy deployment, the different variables that can be used and the areas in which value is created need to be identified. This section first introduces the four variables pertaining to the macroeconomic effects addressed in this report, namely value added, GDP, welfare and employment. It then discusses the opportunities for value creation along the segments of the value chain.

1.2.1 The variables analysed in this report

Among the four variables selected in this report, welfare is discussed only briefly as empirical analysis on the topic is relatively limited.

Value added

Value added refers to the value of goods and services produced, less the value of consumption of intermediate inputs. Here, the value of goods and services is assumed to be determined at market prices. Value added from the renewable energy sector is considered at the micro, meso or macro level (IEA-RETD, 2014, forthcoming), as defined below:

» Micro: From the perspective of an individual firm, value added is a firm´s total sales less the purchases of materials and services from other firms used during the production process. The remuneration to employees and business owners comes from the generation of value added.

» Meso: From the perspective of an entire industry (or economic sector), (gross) value added is the difference between gross output and intermediate inputs. It is the industry's contribution to GDP (UN *et al.*, 2009; Samuelson and Nordhaus, 2010).

» Macro: From the perspective of the economy as a whole, summing up the value added of all producing economic units yields a country's GDP, the most common measure of economic performance.

As a quantitative example of the concept of value added, Table 1.1 shows how it could be calculated at the meso level, by estimating the value added in the photovoltaic (PV) module manufacturing sector. The analysis assumes that individual companies produce only one product for each stage of production. The intermediate products, sold by one company and bought by the next one in the supply chain, are polysilicon, the silicon wafer, and the solar cell, all of which are needed for the final product. At every stage of the supply chain, the producer generates income from the sale of product (sales receipt or turnover) and the value added is obtained from subtracting the cost of intermediate products. The sum leads to a total value added in the complete sector of USD 610 per kW. Notably, most of the value added pertains to the assembly stage of the final product (USD 200 per kW).

Gross domestic product

Another variable studied is GDP, which measures the overall performance of an economy and is the most commonly used indicator of economic activity at a

TABLE 1.1 RECEIPTS, COSTS AND VALUE ADDED OF A PV MODULE AND ITS COMPONENTS

STAGE OF PRODUCTION	SALES RECEIPTS (TURNOVER, GROSS OUTPUT)	LESS: COST OF INTERMEDIATE PRODUCTS AND SERVICES	VALUE ADDED
	USD/kW		
Polysilicon	150	50	100
Silicon Wafer	330	150	180
Solar Cell	460	330	130
Final product (PV module)	660	460	200
Total	**1 600**	**990**	**610**

Source: Based on IRENA, 2012a; Samuelson and Nordhaus, 2010.

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[3]   *It could be argued that externalities should not be included within energy system-related effects, because most of them are borne by agents outside of the energy system (this is precisely the definition of externality). However, the literature seems to place them here, perhaps categorising the externalities by where they are produced and not where they are borne.*

Box 1.1

CONCEPTUAL FRAMEWORK FOR ASSESSING VALUE CREATION IN THE CONTEXT OF ENERGY ACCESS

An estimated 60% of the additional power generation required to achieve the United Nations (UN) Sustainable Energy for All universal energy access target is projected to come from off-grid solutions, both stand-alone and mini-grids (IRENA, 2013a). In this context, decentralised renewable energy systems can play a crucial role, not only because they are already cost competitive in many rural circumstances, but also because they can offer tremendous opportunity for value creation along the energy access value chain, in the form of human and economic development.

There is currently no single internationally accepted definition, and the terms "energy access", "access to energy services" and "energy poverty" often are used interchangeably. Yet there is growing consensus that the definition of energy access should include the provision of clean and affordable modern energy for basic human needs as well as to enable productive uses that foster local economic development. One of the main conceptual challenges in estimating the costs and benefits of access through renewable energy comes from the difficulty of measuring any one of the definitions of access in a precise manner. Most energy access indicators fall short of capturing information on the level (quantity, efficiency) and quality (reliability, affordability) of energy.

Two aspects are critical in describing the full value creation from renewable energy-based access: the need to include productive uses of energy in addition to household energy, and the need to go beyond standard economic indicators.

Over the past decade, several institutions have attempted to develop more comprehensive quantitative approaches for measuring access as well as its benefits including productive and social uses. However, all of these measures are based on existing data, which are inherently limited in their scope. The way forward is to invest in collecting different types of data, particularly on the demand side. The Global Tracking Framework, for example, proposes exploring the feasibility of "global customized energy surveys" and developing "methodologies for measuring access to energy for productive and commercial uses, as well as for heating applications".

Despite this lack of data, there is growing evidence that off-grid renewable energy technologies can create significant value in terms of additional household income and employment opportunities, both in the renewable energy supply chain and in downstream enterprises. IRENA (2013a) estimates that reaching the objective of universal access to modern energy services by 2030 could create 4.5 million jobs in the off-grid renewables-based electricity sector alone. Considerable value creation also can stem from downstream activities enabled by RET installations in the form of local businesses, gains in agricultural productivity and food preservation. Although quantifying these benefits is not easy, they should be taken into account when assessing the full value creation of access to energy.

The second critical aspect for unveiling the full value creation potential is the need to go beyond standard economic indicators, which fail to capture the costs of "deprivation" and therefore cannot account for the positive changes brought on by access. As in the modern market segment, a key challenge is to attribute quantifiable value to improved health, education and gender balance, among others. These variables are particularly important in the case of access given that indoor air pollution, for instance, the use of solid fuels kills 2.4 million people globally every year, mostly children and women.

In general, the concept of GDP has substantial limitations because it focuses on economic performance and overlooks the broader benefits to societies, particularly those related to quality of life (see also Box 1.4). Beyond income and employment, renewable energy-based access generates benefits that can be captured only by alternative welfare measures consistent with the concept of development as the "ability to choose" (Sen, 1999).

This brief exploration of the conceptual framework required to fully capture value creation from renewable energy-based access reinforces the need for a comprehensive framework to collect new data and to analyse and disseminate the multi-faceted effects of energy access initiatives. Comprehensive data on the costs and benefits of energy access can play a crucial role in guiding policy making towards adopting energy access approaches that maximise socio-economic benefits.

country level. GDP and GDP growth serves as a basis for domestic policy debates as well as for international comparisons (OECD, 2001, 2011; Eurostat, 2013). Research shows that the impact of renewable energy deployment on GDP is overall positive despite limitations of existing approaches to assess it, as shown by the examples of Mexico and Japan (see Box 1.2).

A country's GDP can be obtained using different estimation approaches, ideally yielding the same result. Its calculation is based on the System of National Accounts (SNA), which offers three approaches, namely production, expenditure and income (see Box 1.3) (UN *et al.*, 2009; Eurostat, 2013).

Welfare

The measure of GDP can be complemented with various welfare-related indicators developed to quantify economic performance. These indicators range from the concept of welfare in conventional economics to alternative measures of well-being, such as the Human Development Index (HDI) (OECD, 2011; Allan *et al.*, 2012).

In conventional economics, welfare is an indicator of material economic well-being, measured as an aggregation of the utility[4] that consumption or other activities/goods/services (for example, leisure) provide to a group of people. It is

used in economic modelling (see Chapter 3) and analysis to assess the changes in well-being of a society, which are not necessarily reflected in other variables such as GDP.

Alternative welfare measures that differ from the conventional economic terms have been developed within the sustainable development debate (see Box 1.4). These alternative measures implicitly acknowledge the limitations of traditional measures such as GDP or material welfare, but they are not commonly used in economic impact assessments of renewable energy deployment.

Renewable energy deployment can affect many such indicators of well-being. Possibly the most important dimensions are environmental and health-related. For example, power generation and road transport are two of the main sources of air pollution. Subjective well-being is influenced by the quality of the local environment, which also affects environmental health (OECD, 2011). In March 2014, the WHO reported that 7 million premature deaths annually are linked to air pollution; by comparison, the AIDS pandemic killed 2.3 million people globally in 2005, its worst year (WHO, 2014). Renewable energy deployment can provide clean alternatives to power generation and transportation, and hence also improve the respective measures of well-being (Kahn, 2013). It can also play a key role in addressing other important environmental issues such

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Box 1.2

EXPECTED IMPACT ON GDP OF RENEWABLE ENERGY DEPLOYMENT IN MEXICO AND JAPAN

Different approaches may be used to measure the impact of renewable energy deployment on a country's GDP. A study in **Mexico**, for example, used an input-output methodology (see Chapter 3) to assess the impact on GDP of developing 20 gigawatts (GW) of wind power capacity by 2020. It concluded that achieving this target is estimated to lead to an increase in GDP between USD 7.9 billion and USD 28.5 billion, depending on the level of domestic manufacturing of components, representing between 1.6 % and 2.6% of the country's GDP in 2010 (AMDEE, 2013a).

For **Japan**, a comprehensive study on renewable energy deployment which assumed a 2030 target

of 14-16% renewables in the energy mix (including geothermal and hydro), concluded that the benefits are roughly double to triple the cost. The benefits are categorised into 1) savings of fossil fuels, 2) quantified economic value of reduced carbon dioxide (CO_2) emissions and 3) indirect and induced economic ripple effects. Of these categories, the economic ripple effects account for 75-90% of the total benefit. The study estimates, for example, that the cost of installing 23.3 GW of solar PV by 2030 is around USD 39 billion[5] , and the added value reaches around USD 47.5 billion, with new employment of 595 000 jobs (Japan Ministry of Environment, 2008).

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[4]   Utility" is a key economic concept which is little understood, perhaps due to its abstraction. It represents the satisfaction or pleasure that an action (e.g., a purchase, leisure time, etc.) brings to a person. It is not easy to quantify; hence, proxies are used, such as willingness to pay (e.g., the satisfaction produced by a good can be approximated by how much a person is willing to pay for that good).

[5]   Exchange rate of 1 JPY = 0.0098 USD

Box 1.3

DIFFERENT APPROACHES TO CALCULATE GDP

Figure 1.3 presents an overview of the different approaches for estimating GDP. The orange boxes indicate GDP components that are relevant in the context of this report. These include gross value added in production sectors (such as manufacturing and financial services, both of which are needed for renewable energy deployment), net exports (renewable energy deployment can affect the trade balance in important ways, from the perspectives of both fossil fuels and equipment trade), compensation of employees (determined by the number of jobs present in the industries studied) and property income (including, for instance, the profits received by investors in renewable energy assets).

FIGURE 1.2 SYSTEM OF NATIONAL ACCOUNTS AND THREE DIFFERENT APPROACHES FOR ESTIMATING GDP
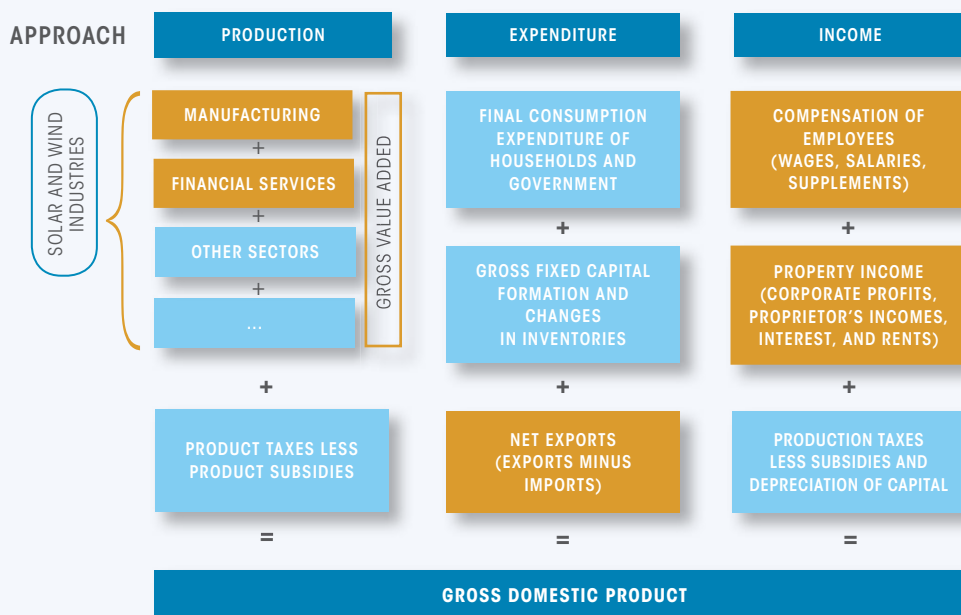
Note: Yellow boxes indicate GDP components that are relevant in the context of this report
Source: UN 2009; Samuelson/Nordhaus 2010; Eurostat 2013

The **production approach** (left column) estimates GDP by summing up the value added of a country's economic sectors (plus product taxes less subsidies). These include, for example, manufacturing, construction, public services, financial services and other sectors. The classifications of sectors in national statistics vary by country, but in most cases they are based on the International Standard Industrial Classification of All Economic Activities (ISIC) (UN et al,, 2009). Because the value added of the renewable energy sector is cross-sectoral, it cannot be found explicitly in national statistics and has to be derived from different branches such as manufacturing or financial services. This is a major difficulty in quantitative analyses of the RET sector, and it calls for improved national economic statistics which ideally include further disaggregation to account for the renewable energy sector.

In the **expenditure approach** (middle column), GDP is estimated through its components: final consumption of households and government, capital formation and changes in inventories, and net exports. Net exports (exports minus inputs) are conceptually similar to a country's trade balance, which relates to the issues of trade in energy products and domestic production (see Section 1.3.).

GDP can also be estimated using the **income approach**, which encompasses the compensation of employees, property income (including corporate profits), production taxes (minus subsidies) and depreciation of capital. This approach is important in the context of this report because it touches on two issues. First, the compensation of employees is crucial for estimating the number of jobs created in the renewable energy sector (for instance, by using an average wage). Second, property income includes corporate profits, which can be distributed across society in various ways, including profits from privately or community-owned RET installations (see Section 1.3). Another way to look at income is at the micro-level, wherein a firm can pay its employees and remunerate its shareholders as a result of the value added it has created through its activities.

as climate change as well as preserving resources (*e.g.*, fossil fuels) for future generations.

In this phase of the "econValue" project, the focus is on conventional welfare approaches, since various related quantitative methods are already well established (see Chapter 3). In later phases, alternative and more comprehensive approaches could be analysed.

Employment

The final key macroeconomic variable examined in this report is employment. IRENA provided a first comprehensive overview of the various dimensions of renewable energy employment in its *Renewable Energy and Jobs* report. Worldwide, there were about 6.5 million direct and indirect jobs in the renewable energy sector in 2013, of which more than 3.1 million were related to solar PV, CSP and wind technologies (IRENA, 2014a). Box 1.5 shows the potential for job creation in India, Japan, Mexico and South Africa, drawn from different case studies commissioned by IRENA. It should be noted that the methods used for these estimations can differ.

Among the controversies in this area are whether job gains from renewable energy are greater than losses incurred in the conventional, fossil fuel-based energy system, and to what extent possible increases in electricity prices related to renewables could lead to employment losses. In other words: does renewable energy deployment lead to net job gains or losses? Some argue that the relatively higher monetary[6] costs of deploying renewables (which no longer holds true in many instances where grid parity is achieved) will reduce purchasing power and consequently employment. Others hold that the decentralised nature of renewables deployment will raise the overall number

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Box 1.4

GDP LIMITATIONS AND ALTERNATIVE WELFARE MEASURES

The concept of GDP is sometimes criticised for its limitations in reflecting the well-being of societies. Among other shortcomings, GDP contains no information about factors such as how resources are shared within society; the stock of different types of "assets" such as a healthy environment and abundant natural resources; human capital/education, well-being or health; social capital; freedom and solid institutions; or household services that are not traded in the market. For example, activities that are counted as positive contributions to GDP can cost human lives or have negative environmental implications, such as vehicle accidents or oil spills (OECD, 2011).

Alternative welfare measures can be used to expand conventional concepts of economic performance to reflect more comprehensive measures of human well-being. The OECD, for example, identifies material living conditions such as income and wealth, jobs and earnings, and housing conditions, as well as additional dimensions related to quality of life, such as education and skills, health status, work-life balance, civic engagement and governance, social connections, personal security, environmental quality and subjective well-being (OECD, 2011). Instead of focusing on economic production, as GDP does, these measures focus on households and individuals and on overall well-being outcomes, as well as on their distribution.

The UN Millenium Development Goals similarly focus on alternative measures of well-being, particularly health education and income distribution (*i.e.*, eradicating extreme poverty). One of the goals is environmental sustainability, a concept that not only refers to current well-being, but also takes into account future well-being (UN, 2013). One prominent example of a country that officially measures a multi-dimensional "Gross National Happiness Index" (with 9 domains and 33 indicators) is Bhutan (Ura *et al.*, 2012).

Clearly, many of these measures influence or are influenced by the level of income. For example, indicators of health, personal security and subjective well-being and other dimensions of quality of life are strongly correlated with disposable household income (OECD, 2011).

The HDI is perhaps the best-known example of an indicator that extends beyond measuring income alone. It is a composite of three dimensions: health, education and living standards, using the respective indicators of life expectancy at birth, mean years and expected years of schooling, and gross national income per capita (UNDP, 2013). Aggregating indicators, as the HDI does, presents advantages in comparison and ease of use, but also creates new problems (such as the need to use uniform units, the inherent loss of information that this entails, and how to weigh the indicators, a choice that requires normative judgement) (Decanq and Lugo, 2009). It is also difficult to choose appropriate indicators for individual dimensions; in the case of the HDI, education was measured previously through literacy rates, now deemed insufficient to adequately reflect knowledge achievement.

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[6]   *Without considering externalities*

of jobs (IEA-RETD 2012; IRENA, 2013a). These arguments underscore the need for more country-specific empirical data and analysis and reliable approaches to estimating the potential for economic value creation from renewable energy deployment. An overview of such approaches is presented in Chapter 3.

Jobs in the renewable energy sector itself are classified as "direct", whereas jobs in supporting industries, such as steel or software, are referred to as "indirect". Jobs in all other sectors that benefit from any of the various macro-economic feedbacks (for example, consumption expenditures by employees in the direct or indirect industries) are defined as "induced" (Breitschopf et al., 2012, IRENA, 2013a). Taking into account indirect jobs in addition to direct jobs may raise employment estimates by 50% to 100% (Rutovitz et al., 2012). This finding is broadly consistent with results from a recent cross-country comparison[7] (Nathani et al., 2012). In it, the ratio of indirect over direct jobs was between 30% and 170%, but most countries showed a ratio of about 60-80% (see Table 1.2). These findings highlight the importance of also considering indirect jobs.

The ratio of indirect over direct jobs can be understood as a measure of the division of labour between the renewable energy sector and its supporting industries. This ratio may differ between industries in the same country and/or between countries for the same industry. It may

even differ between individual firms in the same industry in a single country. Some experts suggest that it depends greatly on each firm's or country's industrial structure, and on the level of domestic manufacturing of renewable energy equipment. The greater the level of domestic manufacturing (and its complexity), the greater the number of suppliers involved, hence the greater the indirect employment (other factors being equal). This, however, may not be the case if supplies are imported. A clear conclusion in this regard would need more research.

Apart from the distinction between direct and indirect, jobs can also be classified based on their durability. For example, jobs in operation and maintenance (O&M) are needed over the entire lifetime of a project, whereas jobs in construction are temporary and needed only once per project. When countries implement predictable long-term renewable energy deployment policies, they promote an RET expansion that can lead to sustainable job creation for all stages of the RET life cycle (IRENA, 2011).

Concluding remarks. Despite their long-standing use and predominance in policy analysis, the four key variables analysed here have clear strengths and weaknesses summarised in Table 1.3. Given these limitations, future impact analyses of renewable energy deployment should enlarge the scope to include other variables (see Section 1.3).

Box 1.5

POTENTIAL FOR JOB CREATION FROM RENEWABLE ENERGY IN INDIA, JAPAN, MEXICO AND SOUTH AFRICA

» **India:** a recent analysis reveals that the total direct and indirect employment from RET amounted to almost 350 000 jobs in 2010, with 42 000 jobs in the wind sector, 112 000 in on- and off-grid solar PV and 41 000 in solar thermal, with the rest being jobs in bio-energy and hydropower. Using moderate- and high-growth scenarios, total future job creation in the renewable energy sector can increase to 589 000-699 000 jobs by 2015 and 1.051 million 1.395 million jobs by 2020 (CII-MNRE, 2010).

» **Japan**: a study by Osaka University considered the effect on employment of increasing the country's 2020 target for renewable energy from 14% to 20% of the energy supply. The analysis projects some 0.3 to 0.6 million new jobs by 2018 (Ono et al., 2012).

» **Mexico**: scenarios on the development of wind and solar capacities, which assume wind capacities of

12 GW and solar PV capacities of 1.5 GW in 2020, result in the creation of 48 000 jobs for wind and 12 000 jobs for solar PV (AMDEE, 2013a, b).

» **South Africa**: scenarios on employment in the wind industry were developed based on a forecast of annual installed wind power capacity to 2020, combined with likely levels of domestic wind turbine development/component manufacture and assumptions about the number of jobs per installed capacity. Under the "central estimate" scenario, based on the Integrated Resource Plan (IRP), 3 800 megawatts (MW) of cumulative wind capacity are added to 2020, and the results indicate that some 1 000 people would be required by 2020 at the technician level, another 1 000 skilled workers for construction and manufacturing, and approximately 350 jobs at the engineer level (GIZ, 2012a).

[7]   *Employment figures were calculated using a consistent gross input-output modelling approach (Breitschopf et al., 2012) as further described in Chapter 3.*

	DIRECT EMPLOYMENT	INDIRECT EMPLOYMENT	RATIO INDIRECT OVER DIRECT
Canada	31 997	21 679	**68%**
Denmark	27 233	21 680	**80%**
France	29 790	19 110	**64%**
Germany	150 057	120 533	**80%**
Ireland	2 573	744	**29%**
Japan	33 574	38 852	**116%**
Netherlands	6 651	11 605	**174%**
Norway	10 778	7 513	**70%**
United Kingdom	16 152	11 027	**68%**

Source: Derived from Nathani et al. 2012

1.2.2 Opportunities for value creation along the value chain

In analysing value creation of renewable energy deployment, the different areas in which opportunies for value creation exist need to be identified. This section defines the concept of value chain and analyses opportunities for value creation from the deployment of solar and wind energy. The renewable energy industry is cross-sectional since activities occur in different economic sectors, as defined in official statistical classifications. As such, analysing the value creation of renewable energy deployment typically follows the "life cycle" approach or the value chain approach in the literature.

The **life-cycle** of a product refers to the whole product-related process from its conception, through design and manufacture, to O&M and disposal (UNEP and Society of Environmental and Toxicology and Chemistry (SETAC), 2009). Often the term "from cradle to grave" is used to illustrate the idea of life-cycle analysis. The life-cycle concept is frequently connected to the approach of value chain analysis, and often the terms are not clearly distinguished. For example, UNEP (2009) notes that "When a product passes from one part of a product chain or life cycle stage to the next, it gains value. At all stages of this process, value is added as it passes through each part of the value chain.

TABLE 1.3 STRENGTHS AND WEAKNESSES OF THE KEY VARIABLES ANALYSED (VALUE ADDED, GDP, WELFARE AND EMPLOYMENT)

VARIABLE	STRENGTHS	WEAKNESSES
Value added, GDP	» Well-established indicators » Data often available through official statistical offices » International and temporal comparison possible	» Does not cover non-market goods and assets (*i.e.*, negative or positive externalities, such as environmental impacts) » Does not contain information on a society's well-being (*e.g.*, how resources are distributed) » Negative implications on environment or people could be counted as positive contributions to GDP (*e.g.*, an oil spill that require more oil production and hiring of cleaning services) » Lack of disaggregated data on renewable energy in national statistics
Welfare	» Well-established indicator	» Similar weaknesses as for GDP and value added (*i.e.*, only considers material welfare) » Conceptually more difficult to comprehend than GDP and value added » Lower compatibility with national statistics
Employment	» Well-established indicator » Important in political and public debates	» Total number of jobs does not contain information about the quality of jobs » Lack of disaggregated data on renewable energy employment in national statistics

The term **value chain** comes from business management theory and was first described by Porter (1985) as a chain of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service to customers, which means all value-adding activities are regarded. In parallel, the term "supply chain management" emerged. In the literature, both terms are often used interchangeably. Throughout this report, the term "value chain" is used, as it can be rather found in macroeconomic oriented analyses, especially those with a focus on RET deployment.

Hereafter, the life-cycle approach is used as the generic basis for the analysis and the different phases can be described as follows:

» **Project planning:** Any preparatory work necessary to implement the project, including concept development and site preparatory works.

» **Manufacturing:** The industrial processes, including the production of machinery, equipment and components.

» **Installation:** Includes infrastructure works and construction of the facility itself.

» **Grid connection:** Planning and construction works related to cabling within the renewable energy project and to connect the facility to the local grid.

» **Operation and maintenance:** After commissioning of projects, the operation phase starts and requires constant technical management and maintenance work to operate the project successfully over its life time. The term "operation" here also implies the selling of electricity.

» **Decommissioning:** When the life time of the project ends, it has to be deconstructed and its components have to be recycled or disposed.

Generally the relationship between the terms of life-cycle and value chain may be best explained by seeing it as two complementary streams: each part of the life-cycle of a RET project can be further analysed by looking at the different sub-products and sub-processes needed to implement this part. Only in their combination they lead to the value of the respective life-cycle part being finalised (similar to the view used in value chain analysis). By the definition of sub-products and sub-processes a

more differentiated point of view is gained, where value chain / supply analysis approaches are also applicable to further evaluate the value creation potential for each sub-step.

Figure 1.4 subdivides the parts of the life-cycle of wind and solar energy projects into examples for relevant sub-products and sub-processes. During each step of the life-cycle and each step of the sub-areas, value is created by all industries involved as well as by the related industries which deliver the respective inputs. Here, value chain analysis can be used to outline the detailed resources, processes and activities needed to implement all those parts.

Delimitation of the RET industry

Overlaps between the RET industry and other industrial branches exist and it is often not clear where to set the boundaries. In the following paragraphs, it is discussed how to deal with this issue during the analysis of value added.

The RET industry encompasses a range of activities that occur in different economic sectors as defined in statistical classifications. Due to this cross-sectional character, the value added of the industry is generally not adequately covered in official statistics (Breitschopf *et al.* 2011). Although the underlying statistical classifications normally tend to get further developed to reflect technological change, the adaptation proceeds only slowly. This is due to the fact that comparisons between nations and over time require a certain stability of the standard industrial categories. Full coverage of the RET-branch by official business statistics is not expected in the short term. Therefore, any in-depth analyses of RET value creation will, for the foreseeable future, depend on self-defined delimitations for data collection (Edler 2013).

The components of a RET system are built up of various sub-components that are not necessarily manufactured by the same company. An analysis of the components, sub-components and materials shows that many of them are not exclusively used in RET; for example, the steel used for wind turbine towers is also used for other products. The challenge of attributing intermediate to final goods is known as "dual use" or "multiple use" (Jordan-Korte 2011). Another hindrance to the clear delimitation of the industry is the existence of wholesale markets and other intermediaries. In such cases, from a company's point of

FIGURE 1.3 Life cycle phases and related sub-processes and products of wind and solar energy technologies

LIFE-CYCLE PHASES	PROJECT PLANNING	MANUFACTURING	INSTALLATION	GRID CONNECTION	OPERATION AND MAINTENANCE	DE-COMMISSIONING
WIND	FEASIBILITY STUDIES	NACELLE	SITE PREPARATION	CABLING CONCEPT	OPERATION	DECONSTRUCTION
	RESOURCE AND ENERGY YIELD ASSESSMENTS		INFRASTRUCTURE WORK	CABLE PRODUCTION	MAINTENANCE	
	ENVIROMENTAL IMPACT ASSESSMENTS	ROTORBLADES			TECHNICAL MANAGEMENT	RECYCLING
	PLANNING APPLICATIONS		FOUNDATION	GROUNDWORK/ CABLING	COMMERCIAL MANAGEMENT	
	APPROVAL PROCESS	TOWER	ASSEMBLY	GRID CONNECTION	SPARE PARTS	DISPOSAL
	INFRASTRUCTURE PLANNING					
SOLAR: PV	FEASIBILITY STUDIES	PV-MODULE*	SITE PREPARATION	CABLING CONCEPT	OPERATION	DECONSTRUCTION
	RESOURCE AND ENERGY YIELD ASSESSMENT		CONSTRUCTION WORK	CABLE PRODUCTION		
	ENVIRONMENTAL IMPACT ASSESSMENTS	INVERTER			MAINTENANCE	RECYCLING
	PLANNING APPLICATIONS	ELECTRICAL COMPONENTS	MODULE INSTALLATION	GROUNDWORK/ CABLING		
	APPROVAL PROCESS				COMMERCIAL MANAGEMENT	DISPOSAL
	INFRASTRUCTURE PLANNING	MOUNTING STRUCTURE	ARRAY CABLING	GRID CONNECTION		
SOLAR: CSP	FEASIBILITY STUDIES	RECEIVER	DETAILED ENGINEERING	CABLING CONCEPT	PLANT ADMINISTRATION	DECONSTRUCTION
		MIRROR				
	RESOURCE AND ENERGY YIELD ASSESSMENTS	PIPES	CIVIL WORKS		OPERATION AND CONTROL	
		HEAT TRANSFER FLUID		CABLE PRODUCTION		
	ENVIROMENTAL IMPACT ASSESSMENTS	MOUNTING STRUCTURE	SOLAR FIELD ASSEMBLING		TECHNICAL INSPECTATION OF POWER BLOCK	RECYCLING
	CONCEPT ENGINEERING	HEAT EXCHANGER		GROUNDWORK/ CABLING	SOLAR FIELD OPERATION AND MAINTENANCE	
		PUMPS	INSTALLATION			
	APPROVAL PROCESS	TURBINE			DISTRIBUTION OF ELECTRICITY	DISPOSAL
		GENERATOR	INFRASTRUCTURE WORK	GRID CONNECTION		
	INFRASTRUCTURE PLANNING	REST OF POWER BLOCK				

*PV-module involves different production steps depending on technology (crystaline silicon, thin film)

Source: Based on EWEA 2012; EPIA et al. 2009; Breitschopf et al. 2011, 2012; Gazzo et al. 2011

view, it may be difficult to identify where the products or components manufactured will finally be used. This problem can be circumvented by applying a demand-oriented input-output framework, in which all necessary intermediate inputs are attributed to the final demand for each product, in our case, RET (OECD *et al.* 1999).

Different stakeholders do not agree on where to draw a boundary to define which activities count as part of the RE-industry and which ones contribute to the rest of the economy (*e.g.* conventional power generation). While wind and solar technologies can be unambiguously allocated to the RET field, one needs to clarify whether the auxiliary technologies (*e.g.* electricity storage, fuel cells, smart grid components) that could complement a large-scale expansion of RET should also be included (completely or only partially) in the core RET industry (Breitschopf *et al.* 2011, 2012).

Within the RET industry, evaluating economic effects and value creation is a complex task, as the activities of the RET sector are very heterogeneous, including *e.g.* production, construction, operation & maintenance, consulting, administration and financial issues. The relevant companies might have their central focus on RET technologies, or they might be active on the periphery of the RET branch or might also be suppliers to the RET industry – beside other activities

In each life-cycle phase of a RET project, economic activities trigger expenditures and lead to value creation. The next section looks closely at the kind of potentials for value creation along the RET life-cycle, hereafter referred to as RET value chain.

Analysis of domestic value creation opportunities along the solar and wind energy value chain

Analysing the potential for value creation of renewable energy often addresses whether this potential can be realised "on site" of a specific project (*i.e.*, if value creation is achieved where the solar or wind project is located), or if certain segments of the value chain are covered through imported products or services. Depending on the maturity of a country's renewable energy sector, more or less value may be created domestically. If the local economy cannot provide the required input to a segment of the value chain, the input needs to be imported, for example through external expertise in project development or imported material (MWGSW, 2011).

The following section provides technology-specific examples of value creation potential at each segment of the value chain and supporting processes (see Figure 1.4), illustrated by country case studies.

Project planning refers to the initial preparatory and planning activities for setting up a renewable energy project. It includes activities that range from resource assessments and feasibility studies to the planning of infrastructure. This requires specialised and experienced personnel. In general, the higher the number of projects developed in a country, the higher the number of domestic specialists available and the larger the share of domestic value creation. In countries where the sector is less mature, foreign consultants are often involved in project planning and development. However, local expertise is preferred in some areas, such as in the approval process which includes legal and administrative steps. Local experts should ideally be consulted in environmental and development issues. This highlights the role of education and training

FIGURE 1.4 TYPICAL SEGMENTS OF THE RENEWABLE ENERGY VALUE CHAIN
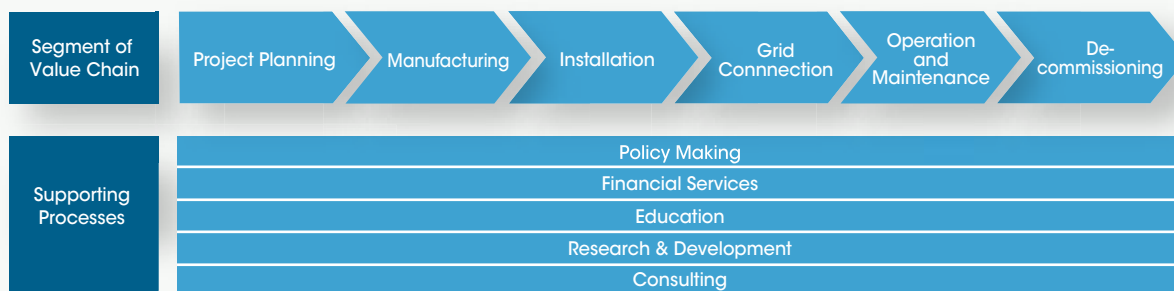
Source: Based on MWGSW, 2011.

8   Usually, firms are assigned to industrial branches based on their main products or processes (principle of predominance). Consequently, one has to decide how to distinguish key processes from ancillary processes.

policies in bridging the skills gap that exists in some cases, in order to retain the value creation locally (see Chapter 2).

For **wind energy** projects, the planning and development process is normally undertaken by project developers, who either operate the project themselves or sell it to other operating companies (EWEA, 2012). Planning for **Solar PV** projects mostly entails the planning and projecting of modules. Depending on the project size (rooftop or ground-mounted PV), such tasks can be undertaken by the installer, or a project developer could be involved. For **concentrated solar power plants**, project planning and development encompasses many steps that include conducting a basic scope, concept engineering and geographical determination. Therefore, at least one engineering company or project developer is needed, with the potential for more companies or consultancies to be involved (Gazzo *et al.*, 2011).

Manufacturing of wind turbines, solar modules and concentrated solar power (CSP) components requires a certain degree of industrial capability and offers considerable job creation potential (see Box 1.6), depending on the level of sophistication of the components and the level of mechanisation of the production process. Value can be created in each step of manufacturing, from the sourcing of raw material, to component manufacturing, to assembling. It is useful to distinguish RET components by versatility and grade of simplicity to estimate the value creation opportunities not only for a single technology, but also for broader RET development and to generate synergies.

A recent study undertaken in the Middle East and North Africa (MENA) discusses the concepts of "versatility" (defined as the adaptability of a component to different types of RET) and "simplicity" of a component (measured in technological, financial, market and quality terms) that are used to analyse the potential for domestic value creation. Some components are more versatile, as they can be utilised for more than one RET, and some tend to be simpler to produce. Combined with the local industrial conditions, components with high versatility and grade of simplicity – such as structural steel elements and cables – are found to be more likely to be manufactured locally (Dii, 2013).

The expansion of global **wind energy** deployment can offer substantial benefits for the domestic manufacturing sector. For example, in the United States, many of the capabilities needed to manufacture wind turbines are available domestically, and necessary changes to start contributing to wind turbine manufacturing can be made more or less easily (*e.g.*, for tier-three suppliers, who provide raw materials or basic components). Due to similar industrial processes, wind energy could help to revive manufacturing jobs which have been lost in other sectors such as the automotive industry (CGGC, 2009). Moreover, there are relevant effects on other industries, especially the steel industry. Steel is one of the most important materials of a wind turbine and accounts for up to 90% of the machine by weight, depending on the turbine design. Box 1.7 discusses the wind manufacturing sector in India.

In countries with a nascent renewable energy sector, opportunities for producing complete wind turbines are limited. The wind turbine market is a global market with tough competition and domestic/regional demand for turbines may be a key consideration when assessing the feasibility of setting up a turbine factory, in terms of market size assessment. In 2012, the ten largest wind turbine manufactures supplied 77% of the

Box 1.6

EMPLOYMENT IN MANUFACTURING OF SOLAR PV AND WIND COMPONENTS

In Japan, a study analysing the employment potential (direct and indirect) related to manufacturing, construction and O&M of solar PV and wind power technologies shows that employment in manufacturing accounts for about 70% of overall employment for both PV and wind (Matsumoto *et al.*, 2011). Japan also has a competitive edge in the wind industry, including activities related to manufacturing components (*e.g.* machinery, electronics, materials, etc.), installation, and construction and consultancy services. Approximately 20 000 jobs have been created in the Japanese wind industry (Komatsubara, 2012).

global market (REN21, 2013). In a country at the early stage of wind energy development, there is a need to verify whether the demand for RET is sufficient to build up local manufacturing facilities (for complete turbines or just components or assembly).

This was the case in large markets such as China and Brazil (IRENA, 2013b), but it is not so clear in other markets, such as South Africa. If this is not the case, alternative strategies may be more feasible. For example, value can be created on-site by involving local subcontractors. In addition to manufacturing activities, the supply of raw material or sub-components offers an economic opportunity for component manufacturers and other industrial sectors. However, the logistical requirements of handling large wind components is also a factor to be considered in the decision to manufacture locally. These are discussed later in the section.

For **solar PV** plants, the manufacturing process includes the different production steps of a PV module from silicon in addition to components for the balance of system, including the inverter, mounting systems, the combiner box and miscellaneous electrical components and optionally battery and charge/discharge controlling systems (IRENA, 2012a). Setting up domestic PV production plants needs serious consideration. With falling global PV prices, existing manufacturing overcapacities and the ongoing consolidation in the market, new domestic PV production facilities may be risky (Lehr, 2012b; REN21, 2013). Box 1.8 discusses solar manufacturing activities in Malaysia.

Manufacturing **CSP** plant components, such as mirrors, receivers and power blocks, involves different industry sectors, with varying potential for local value creation. CSP technology components such as bent glass for the parabolic mirror need to be produced by highly specialised manufacturers, unlike the production of steel or cables (Gazzo *et al.*, 2011). Hence, the potential for value creation in this sector is not applicable to any other market. In addition, the potential for value creation also differs according to the CSP technology. For instance, a large portion of the components of a central tower can be manufactured locally, compared to a parabolic trough. This was the case in Morocco (Gazzo *et al.*, 2011).

Installation includes infrastructure works and the assembling of the wind or solar plant. After developing an installation and infrastructure plan, this phase includes labour-intensive civil engineering infrastructure works – including groundwork, foundations, channelling, water supply, buildings and roads that are typically delivered by local companies. With regard to system installations, developing complete installation services is more complicated for imported equipment, as the manufacturers are typically responsible for the installation activities and normally provide their own equipment and personnel. Local companies can still participate in delivering required services, especially if synergic activities/expertise already exist in the country. For example, builders of offshore oil platforms could be employed in building offshore wind farms.

In the case of wind, the logistical difficulties associated with transporting turbines is characterised by unique challenges and opportunities, because the components have an unusual weight, length and shape and require special equipment to move very large and heavy cargo. There are considerable opportunities

Box 1.7

WIND ENERGY MANUFACTURING IN INDIA

India is emerging as a major wind turbine manufacturing hub. Indian manufacturers are able to keep production costs low, using cheap domestic labour. They then export the wind turbines and blades to a number of countries including, Australia, Brazil, Europe and the United States. Annual production capacity, as of 2012, is now over 9 500 MW, with some international companies sourcing over 80% of their components through their subsidiaries in India. As of 2012, an estimated 391 000 people were employed in India's wind industry (IRENA, 2013). The

2012 Greenpeace India Energy [Re]volution Report, which presented a roadmap to achieving a sustainable energy system in India, estimated that the country's wind industry will employ up to 1.7 million people by 2030 (Greenpeace International, Global Wind Energy Council (GWEC) and European Renewable Energy Council (EREC), 2012).

SOLAR MANUFACTURING ACTIVITIES IN MALAYSIA

Malaysia's manufacturing sector is a major contributor to the country's economic growth. In 2008, the bulk of manufacturing activities were concentrated in the Electrical and Electronics (E&E) sector, mainly in semi-conductors. The local E&E industry is a leading sector which contributes 55.9% of the country's exports and employs 28.8% of the national workforce (PEMANDU, 2013). The E&E sector has a strong linkage with renew-able energy development in Malaysia through providing supporting services. In the search for natural resources,

Sarawak, with its hydropower energy at very attractive rates and high-grade silica deposits, has been charac-terised as a good location for silicon production plants. Advance material production encompasses substrate manufacturing, with companies in this field able to supply solar industry players as well. According to a Malaysian Economic Transformation Programme report from 2012, the completion of a single plant for metallurgi-cal grade silicon, a component of solar panel produc-tion, will create some 600 new jobs (Pemandu, 2013).

for existing transportation providers in the wind energy sector. For example, for an entire project of 150 MW, transportation requirements could be as much as 689 truckloads, 140 railcars and 8 ships (Tremwell and Ozment, 2007, in: CGGC, 2009).

With a growing wind energy industry, demand for logistical services increases, which could lead to the development of a specialised sector in the transporta-tion industry, which is mostly locally based. This could potentially create many jobs throughout a country. Wind energy projects are often based on turnkey construction contracts, which include engineering, procurement and construction services, including civil works, laying cables for electrical infrastructure, and the installation of wind turbines. The on-site construction in-cludes excavating access roads and installing founda-tions for wind turbines. During all those parts of turnkey installation processes, engineering and technical as well as construction personnel are required and there is potential for the development of a domestic industry (CGGC, 2009). Smaller, decentralised systems also can provide an important opportunity for value creation. Rooftop PV, small community solar PV, and small tur-bines (e.g., for well pumps) can be installed by trained local personnel, offering significant potential for value creation (Lehr et al., 2012b).

Grid connection of RET plants is based on the local grid requirements, which depend on the grid operator. The developers of RET projects normally assess those requirements and then contact the grid operator to develop a grid connection agreement. The task of grid connection includes planning work, such as de-veloping a cabling and grid connection concept. In

addition, the on-site construction and cabling work is undertaken during this phase.

The local grid operator normally is tasked with inte-grating renewable energy power plants into the grid systems, which creates value domestically, usuallly associated with high qualification jobs within the grid operator. Furthermore, in the field of grid construction works, as in ground works, cable production and instal-lation, local companies can easily become involved, thereby creating jobs. Moreover, value might be gained through the development and reinforcement of the grid and the resulting increase in security of sup-ply and energy access, even if the increased balanc-ing costs should also be considered.

For instance, **wind** energy grid connection work consists of cabling work within the wind farm itself (cables be-tween turbines) as well as the cabling work necessary to connect the whole wind farm to the grid. The cabling plan is often completed as part of the project planning phase, or it can be done by the manufacturer. The con-struction works related to the grid connection offer con-siderable opportunity for domestic value creation since they generally are conducted by local companies.

Operation and maintenance is a long-term activity that has significant potential for value creation, espe-cially in terms of jobs. Operation includes day-to-day procedures such as monitoring plant operation, responding to faulty events and co-ordinating with the utility. Maintenance work includes both scheduled (preventative) services, such as periodic equipment inspections, and unscheduled services to repair com-ponents in case of failure (Walford, 2006).

O&M offers opportunities for domestic value creation for all countries, independently of their local RET manufacturing capabilities. Even though RET manufacturers often offer full-service contracts with their own personnel, O&M can also be undertaken by national or local staff present at the site. Non-productive downtime hours, which refers to times of poor or non-operation of the plant, are extremely costly for the plant operator; hence, good quality O&M work is crucial. Additional value is generated for the owner of a plant through the sale of electricity.

For **wind** energy plants, local personnel can be integrated into O&M processes from an early stage of development, but a longer time horizon is needed until specialised companies emerge locally. If demand increases, creating a market, developers and manufacturers could consider the establishment of local O&M subsidiaries. Turbines are typically supplied with a warranty of a number of years (depending on the specific contract), which includes maintenance. After the warranty expires, independent companies can be hired for maintenance services. Furthermore, there is also a requirement to provide operational services of the wind farm. Usually maintenance contracts include operation services, but some wind farm owners employ their own operations staff. In addition to the direct labour, supervision, logistical and administrative support is required (O'Herlihy & Co. Ltd, 2006).

PV plants also require regular maintenance, including the inspection of all plant components for mechanical damage, check of the measuring, safety and transmission system, and optional cleaning of the modules. These can be done by local staff. For larger ground-mounted plants, O&M services are needed more frequently, including cleaning of the modules, painting, keeping the site accessible, check on the electrical installations, structural repairs, and integrity of security measures (Belectric, 2013).

O&M of CSP plants is more complex as it includes plant administration, operation and control and technical inspections for both turbines and collectors.

The employment factor for manufacturing, construction and installation activities, defined as the number of jobs necessary to manufacture, build and install one unit of renewable energy generation capacity, differs by technology and by year and country/region, as shown in Table 1.4. The table also shows the

employment factor of O&M activities for the same year/regions.

Decommissioning of RET plants at the end of their lifespan can comprise recycling as well as disposal of components. This phase is of increasing importance, with many RET plants reaching the end of their lifespan in the coming years in countries where RET development started in the 1990s. Usually, the project operator is responsible for dismantling and recycling an installation after it has reached the end of its lifespan. The field of recycling and reconstruction depends on local requirements and conditions.

When recycling policy exists, value is created in the establishment of related recycling industries. The residual value[9] of the assets is to be considered as part of the economic analysis.

To deconstruct a **wind** power plant, heavy lift services are necessary. Local companies can participate in demolition, reinstallation or recycling, if they have the necessary equipment on-hand. In addition, there is the possibility to resell the old turbine. In this case, often specialised companies are involved which update the turbine's technology and review its technical condition, to see if the plant can expand its operation period. The purchase of second-hand wind turbines is an option for some developing countries, which cannot afford new equipment (Welstead *et al.*, 2013). If the turbine cannot be reused, materials, such as steel and copper, can be recycled. For all the steps it takes to deconstruct a wind turbine, personnel is needed. Further value can be created by reselling the turbine or the materials retrieved from recycling.

Recycling of **solar PV** modules requires trained staff with specific skills and knowledge about recycling processes in relation to solar cells, silver, glass, aluminium, foils, electrical components, copper and steel components (EPIA *et al.*, 2009). Therefore, the percentage of local jobs generated depends on the qualifications in the respective country. If the necessary technical background or training is available, local value creation can be high.

The decommissioning of CSP plants shares some similarities with wind and PV, even though the industry cannot rely on much experience yet. CSP plants hold the potential for re-powering at the end of their lifespan,

TABLE 1.4 EMPLOYMENT FACTORS FOR WIND, PV AND CSP TECHNOLOGIES

TECHNOLOGY	MCI (Jobs per newly installed MW)	O&M (Jobs per MW)	REGION	YEAR OF ESTIMATION
Wind, onshore	8.6	0.2	OECD countries (Average values)	Various (2006-2011)
	27.0	0.72	South Africa	2007
	6.0ᵃ	0.50	South Africa	NA
	12.1	0.1	United States	2010
	8.8	0.4	Greece	2011
Wind, offshore	18.1	0.20	OECD countries (Average values)	2010
PV solar	17.9	0.30	OECD countries (Average value)	Various (2007-2011)
	69.1	0.73	South Africa	2007
	25.8	0.70	South Africa	NA
	20.0	0.2	United States	2011
CSP	18.0	1.33	South Africa	2007
	36.0	0.54	South Africa	NA
	7.0	0.6	Spain	2010
	19.0	0.9	Spain	2010

Source: IRENA, 2013.

and components such as steel and copper may be recycled by specialised companies (Deign, 2010).

Value creation potentials of supporting processes

Supporting processes complement the life cycle of wind and solar energy projects and include policy-making, financial services, education, R&D and consulting. All of these activities can occur along the different segments of the value chain.

Policy-making is needed to drive and set the frameworks for renewable energy deployment in a country. Enabling policy frameworks help overcome institutional barriers and market failures to create an environment in which technologies and markets can evolve together. They are most effective when they provide a transparent, consistent, long-term perspective for investors with an adequate risk-reward ratio (Mitchell *et al.*, 2011; IRENA, 2012c). Policy-making is normally an essential first step to incentivise investments in wind and solar energy projects and all related value creation potentials described in this report. In governmental organisations on the national as well as on the regional level, specialised personnel is required to establish the

appropriate frameworks. Box 1.9 discusses Malaysia's renewable energy policy.

Financial services are also crucial for development of a renewable energy sector. The financial sector, banks in particular, evaluate the commercial viability of renewable energy projects and tenable new financial business opportunities. The scope of financial service involvement in renewable energy development is affected by the types of RET owners, which can range from companies to private households. Box 1.10 discusses innovative renewable energy financing approaches taking place in Mexico.

Education and training is needed in order to meet the skills demand of the growing renewable energy sector. There is potential for value creation on three levels: in the renewable energy sector, in the education and training sector, and the intrinsic value of renewable energy-specific education and training.

Adequate training and education is crucial to develop the skills needed to ensure the successful deployment of renewable energy. As such, comprehensive strategies are needed to ensure that the requirements for renewable

Box 1.9

In Malaysia, the National Renewable Energy Policy and Action Plan was conceptualised with a vision of achieving socio-economic development. The policy identified five strategic thrusts to achieve the objective of socio-economic development linked to renewable energy deployment. The core strategic thrust is to introduce an effective legal and regulatory framework for the implementation of renewable energy. The other four complementary strategic thrusts aim to 1) provide a supporting business environment for renewables, 2) intensify the human capital development, 3) enhance R&D in the renewable energy sector and 4) create public awareness and renewable energy policy advocacy programmes.

The National Renewable Energy policy is designed with an approach of evaluation criteria and value creation as success indicators. This approach creates a baseline against which evidence can be obtained to determine if any improvement or positive progress has been achieved. The data obtained in subsequent years will help determine if there has been improvement from the baseline or otherwise. This provides the empirical evidence necessary for continued support of the policy. The policy also suggests that the value created should be evaluated periodically.

energy skills, education and training are met. In the absence of locally available skills, investors are less likely to develop projects. If they do, it is at higher costs because of the need to hire people from abroad. For instance, more than 20 000 EU professionals are employed by EU-based wind energy companies in non-EU countries (EWEA, 2012).

There is a variety of lessons on how governments have integrated education and training into national renewable energy support policies in recent years (Chapter 2).The education sector and other relevant stakeholders have contributed to bridging the skills gap in many successful examples. Box 1.11 discusses education and training initiatives in the Economic Community of West African States (ECOWAS).

Offshore **wind** energy is a relatively new technology that faces significant challenges when it comes to the availability of human resources, since it requires new types of skills that are not found in the onshore wind industry. As a result, project developers have resorted to other sectors, such as the oil and gas industry, to secure skilled personnel. For example, Denmark and the United Kingdom were able to develop their offshore wind industry by hiring people from the long-standing oil and gas industry.

Research and development services are usually carried out by experienced specialised institutions. The domestic value added during the early phase of renewable energy sector development can be limited, although governments can develop strategies to build up local R&D progressively. As the sector matures, it can bring a substantial value added, for example by patent applications and the resulting possibilities of commercialisation through granting licences. Moreover, R&D and the created new knowledge may lead to positive externalities that are beneficial for society as a whole, but that are not correctly priced in the market and therefore

Box 1.10

In Mexico, Baja California will host the largest solar park in Latin America: Aura Solar I, with 30 MW, 100 hectares and 135 000 panels. Construction is expected to finish in 2013. The company Gauss Energía will provide USD 25 million, while Nacional Financiera and the World Bank will provide USD 75 million to develop the project.

Also, Acciona has recently financed USD 300 million for the Oaxaca II and IV wind power generation projects with an innovative financing mechanism (by issuing investment-grade green bonds). Such mechanism has the potential to mobilise a large part of the investment needed for large-scale renewable energy deployment. It also presents significant opportunities for value creation in the financial sector itself.

not as valuable to the innovator (Mitchell *et al.*, 2011). Box 1.12 discusses some of the related R&D initiatives in ECOWAS.

For example, in the United States, about 3 600 employees of the U.S. Department of Energy's (DOE) laboratories were associated with renewable energy R&D in 2006 (Worldwatch Institute, 2008), and between 2003 and 2012, about 17% of the funding spent in R&D at the DOE was associated with R&D projects in renewable energy – the third largest after fossil and nuclear energy, with each gaining around 25-26% of the whole R&D budget (Sissine, 2012).

Many countries have established knowledge centres related to wind energy research. For example, the U.S. National Renewable Energy Laboratory's National Wind Technology Center is one the leading wind power technology research facilities in the country. In Spain's Navarra region, a competence cluster for wind energy has been established where many research projects are conducted, focussing on fabrication and materials and also on cost decreasing potentials (CGGC, 2009). In Europe, R&D expenditure on the wind industry was about 5% of the industry's turnover in 2010. This is more than two times higher than the average R&D expenditure across the whole European economy, which is about 2% of GDP. In this way, R&D-related jobs are created, and research results ensure competitive technology development in a global market (EWEA, 2012).

With regard to CSP, the Platforma Solar de Almeria (PSA) in Spain, researches, develops and tests these technologies. As the largest European centre, PSA is part of an integrated R&D division within the Centro de Investigaciones Energeticas Mediambientales y Technologicas (CIEMAT) at the Department of Energy. By the end of 2012, 51 researchers were working permanently at the PSA, and 86 persons were working in administration, maintenance and other supporting services (CIEMAT, 2013).

Consulting activities can take place throughout all the segments of the value chain. Small-to-medium companies can rely on consulting services to complement their in-house competence for the implementation of complex projects. Consulting can be required in many different parts of project development, referring to, for example, technical expertise, legal competence, tax legislation or financial issues. In countries with a nascent renewable energy industry, the potential for domestic value creation from consulting may be small, since these services would most likely be provided by international consultants.

Wind energy projects are often complex and require many years of planning, depending on a country's regulations and the status of wind energy development. In general, many different stakeholders have to be consulted. This leads to a demand for consulting services that include, for example, lawyers to assist in drafting and reviewing contracts and legal structures, technical consultants to evaluate the wind potential

Box 1.11

EDUCATION AND TRAINING INITIATIVES IN ECOWAS

The different ECOWAS member countries have started tailoring aspects of their educational and training policies and approaches to support renewable energy deployment. In Ghana, for example, the Kwame Nkrumah University of Science and Technology (KNUST), in collaboration with several partners from other countries, started offering an MSc Programme in Renewable Technologies in 2011 by e-Learning, supported financially by the EU (KNUST, 2011). The main objectives of the programme are two-fold: to increase the number of skilled engineers in renewable energy, and to enrich the knowledge of key actors, including energy policy makers and entrepreneurs, on related issues. Achievement of these objectives will foster consumer confidence in

renewables and boost dissemination of these technologies, which will in turn create employment opportunities in the sector, along with other socio-economic effects.

Trainings are also taking place in universities in Benin, Burkina Faso, Cape Verde and in other capital cities such Dakar and Bamako. The Faculty of Science and Technology at the University of Bamako also carries out studies related to RETs (Coulibaly and Bonfiglioli, 2011). In the case of Nigeria, the Energy Commission, in collaboration with other private sector players such as non-governmental organisations, has been undertaking training in renewables, especially in installation and maintenance.

on a specific site, tax advisors to help find the right strategy related to fiscal issues and biologists to assess the environmental impacts of a project.

Concluding remarks

Value is created in each segment of the value chain as well as in the supporting processes. The potential of domestic value creation depends on the development status of the domestic renewable energy sector. Table 1.5 summarises the outlined potential for domestic economic value creation for each segment of the value chain and by level of industrial development.

Table 1.5 shows that at the beginning of wind and solar energy development, the potential domestic value creation is limited. Production facilities as well as the required skills and knowledge are not available on the local level. With regard to manufacturing, some authors argue that countries should focus first on components with high versatility and low complexity, which will allow them to gradually increase domestic value creation (Dii, 2013). Until the first RET plants are established, local value creation might occur mainly in the fields of cabling and grid construction works, O&M as well as financial services. However, it could be argued that more complex components may be manufactured in synergic industries, or in the case of countries with ambitious industrial policies combining R&D, cluster and training, and aiming to create a full-fledged local value chain.

As shown in Table 1.5, at the early stages of development of the solar and wind industries, the potential for domestic value creation is relatively low in most of the segments of the value chain. Normally at this level of development of the sector, equipment is imported as the domestic manufacturing capabilities could be limited, and installation services are normally imported as they are provided by the suppliers of equipment. With the limited availability of knowledge and experience locally, even project planning could be outsourced to international experts. Value creation is more concentrated in support services such as financing and education and training, and it is relatively significant in grid connection and policy-making.

Once a robust policy framework is established and the already developed projects have proven reliable, investing in renewable energy becomes more attractive and the market picks up. Depending on the country's set strategy, manufacturing activities can begin and value can be created in several segments of the value chain including manufacturing (and the accompanying needed R&D) and installation. Moreover, with the strengthening of local capabilities, more activities, such as project planning, are undertaken by local suppliers. As deployment increases, more O&M activities are needed, which increases the potential for value creation in that area.

As the industry develops, value creation increases along all segments of the value chain (given that the country is producing technologies locally and not importing). The industry matures and activity picks up in areas such as

TABLE 1.5 POTENTIAL DOMESTIC VALUE CREATION DEPENDING ON THE STAGE OF INDUSTRY DEVELOPMENT

POTENTIAL FOR DOMESTIC VALUE CREATION	STAGE OF DEVELOPMENT		
	BEGINNING OF WIND & SOLAR ENERGY DEVELOPMENT	FIRST PROJECTS REALISED, LOCAL INDUSTRIES SUITABLE FOR PARTICIPATING	MANY PROJECTS REALISED, NATIONAL WIND/SOLAR INDUSTRY DEVELOPING
Lifecycle phase			
Project planning	Low	Medium	High
Manufacturing	Low	Medium	Medium / High
Installation	Low	Medium	High
Grid connection	High	High	High
Operation & maintenance	Medium	High	High
Decommissioning	Low	Low	Medium
Supporting processes			
Policy-making	High	High	High
Financial services	Low/Medium	Medium	High
Education and training	Low/Medium	Medium	Medium/High
Research & development	Low	Low/Medium	Medium
Consulting	Low	Low	Medium

Source: based on MWGSW 2011

R&D and consulting. As projects reach their end-of-life, value is created in the dismantling segment as well. The potential for policy-making remains high throughout all levels of development of the industry, as policies should be continuously monitored and adapted to changing market conditions. This is further discussed in Chapter 2.

1.3 VARIABLES FOR FUTURE ANALYSIS

Macroeconomic effects

Mainstream macroeconomic aspects such as GDP and employment form the core of this report and are described in detail in Section 1.2.1. One identified macroeconomic variable left for future analysis is the trade balance. A country's **trade balance** includes imports and exports of goods and services (Mankiw, 2010). In the context of renewable energy deployment, two elements of the trade balance are most relevant: trade in energy products such as fossil fuels, and trade in goods and services related to renewable energy (*e.g.*, solar panels, components or consulting services).

Trade in energy products covers trade in final energy (*e.g.*, electricity), in primary energy (*e.g.*, crude oil) or in other natural resources needed to produce energy (*e.g.*, raw uranium ore). It is estimated to represent

more than 20% of world trade by value (UNEP, 2013a), mainly fossil fuels. In this context, it is helpful to distinguish the perspectives of fuel-exporting versus fuel-importing countries.

For fuel-exporting countries, renewable energy deployment can be a way to minimise domestic use of fuels and maximise the amount available for export. Several oil producers are starting to adopt renewables, in part for this reason. The countries of the Gulf Cooperation Council have set renewable energy targets that, if realised, would save an estimated 3.9 billion barrels of oil equivalent cumulatively between 2012 and 2030. This would yield savings of approximately USD 200 billion (Ferroukhi *et al.*, 2013).

For fuel-importing countries, renewable energy deployment can substitute imports which would be used for power production or other uses. This effect could be one of the main economic benefits of renewable energy deployment. In 2011, global spending on net imports of fossil fuels amounted to USD 2 trillion, of which more than USD 230 billion was spent in China (about 3% of Chinese GDP) and USD 120 billion in India (nearly 7% of GDP). Decreasing these imports can lead to considerable

savings: Spain's use of renewables (for all sectors) substituted about USD 2.77 billion of fossil fuel imports in 2010, and Germany saved about USD 13.5 billion in 2012 (Deloitte and APPA, 2011; BMU, 2013b; IEA, 2012; IMF, 2013). The use of domestic renewable energy sources could specially benefit countries with large trade balance deficits, which may be largely due to energy imports. It can also ease pressure on government budgets in countries with subsidised fossil fuel consumption.

Trade in goods and services for RET deployment for RET deployment is growing significantly. Between 2007 and 2011, world imports of RET equipment increased by more than 60%, double the growth in merchandise imports overall. The two largest national markets are the United States and China: in 2011, firms based in these two countries traded more than USD 6.5 million in solar energy products and more than USD 0.9 billion in wind energy goods and services (UNEP, 2013a).

Trade in goods and services for RET deployment also includes equipment for building up factories for RET equipment (*e.g.* a wind turbine factory). For example, Germany, the United States and Japan have sold turnkey production lines to China, which, on this basis, was able to develop its solar PV industry (UNEP, 2013a). Emerging countries represent an increasing share of renewable energy equipment exports. China is the world's largest producer and exporter of solar PV equipment. So far, however, only a few of these countries are major exporters (UNEP, 2013a).

The deployment of renewable energy does not always influence the trade balance positively. A renewable energy deployment policy which reduces imports of fossil fuels could equally increase imports of renewable energy equipment (for example, solar panels produced abroad), which could result in a null (if not negative) impact on the trade balance. However, the imported RET would enable the reduction of fossil fuel imports for a significant period of time (*e.g.*, 20 years), meaning that the long-term effect on the trade balance is likely to be positive.

If local production of RET equipment is required, considerations to analyse include technology-specific characteristics and logistical issues (such as the decision to manufacture wind towers that are difficult to transport

closer to the site), as well as strategic decisions to develop a local industry. The potential of a country to produce domestically depends on many factors (see Section 2.3), including domestic capabilities; the size of local, regional and international markets; or the status of local renewable energy development. The following example, albeit simplistic, may be illustrative. At the beginning of renewable energy development, domestic production is likely to be restricted to cabling and grid construction works, O&M, as well as financial services. Subsequently, more local sub-contractors and suppliers can be involved, ranging from manufacturing to installation. After many renewable energy projects have been realised and a policy framework has been established that enables a sufficiently large domestic market, local manufacturing of products becomes feasible and specialised services for the renewables sector can be developed.

Many countries are introducing local content requirements, linked to renewable energy support policies, as a means to establish and support nascent domestic renewable energy industries. This should be done with great care, ensuring that the requirements are time-bound, linked to a learning process, and support the creation of a solid domestic supply chain and a skilled workforce (see Chapter 2 for more on these policies). A critical precondition for a domestic RET development path is the availability of sufficient skilled labour and expertise at all stages of the renewable energy life cycle. From an investor's perspective, the potential advantages and disadvantages of engaging local actors have to be considered (see Table 1.6). Government policies that can address some of these issues are discussed in the skills policy section of Chapter 2 and they have also been studied in more detail in IRENA's Renewable Energy and Jobs report (IRENA, 2013).

Distributional effects

A second category of value creation that can be considered in the socio-economic impact assessment of renewable energy deployment is the distribution of value – that is, its allocation across the different types of owners of renewable energy plants and regions, and across energy consumers and tax payers. Further aspects could be the distribution across branches or segments of the workforce, for example, by gender (IRENA, 2011).

Type of owners. Renewable energy plants generate income for their owners during their operation. Traditionally, conventional power plants have been owned and operated by utilities. Given the variable scale of RET, however, a broad variety of owners can be involved, ranging from private companies to individuals and communities.

Overall, only few and scattered data are available on RET ownership worldwide. For solar PV, simple initial estimates for selected countries could be derived from statistics on the number of distributed plants (IEA-PVPS, 2012). This is because distributed PV installations are often owned by private individuals and centralised plants by companies and utilities. In Germany, for example, about 46% of cumulative installed RET capacity was owned by private individuals by the end of 2012 (AEE, 2012, 2013). For wind projects, only about 2% of the total wind capacity installed in the United States included local ownership in 2011 (Slattery *et al.*, 2011). However, community-based approaches to RET are attracting more interest worldwide, due to their contribution to increasing social acceptance of renewables (see Box 1.13) (Bridle *et al.*, 2013; Musall *et al.*, 2011; Schreuer *et al.*, 2010).

Distributional issues are putting pressure on the traditional business models of centralised utilities, and are creating frictions with new entrants into the sector. Future research could explore such issues, as well as global RET and community ownership structures. This may also include ownership of electric grids that are extended specifically for RET deployment.[10] Possible questions include: How and under what institutional arrangements does community ownership affect RET acceptance? How are other characteristics of project development influenced by community ownership (*e.g.*, speed of project planning and implementation)? How does this affect local economic value creation (*e.g.*, revenue management issues)?

Regional distribution. Assessing the regional distribution of value creation includes analysing the effect of renewable energy deployment at the sub-national level- states, provinces, regions, municipalities or districts. Such a spatially disaggregated analysis can serve several purposes.

First, it can provide an overview of the diversity of renewable energy-related developments and shed more light on geographical patterns of structural change. In Germany, for example, the gross employment due to renewables overall is higher in the eastern than in the western states (BMU, 2012). Second, regional analysis can help with policy-making at a sub-national level as well as the monitoring and evaluation of sub-national initiatives and policies. It is worth noting that the political priorities of sub-national governments may or may not align with federal priorities. Third, such information can help in raising social buy-in and public support.

Although geographically disaggregated data on installed renewable energy capacities are often available (for example, in the U.S. State Clean Energy Data Book (DOE, 2010)), comprehensive and consistent empirical analyses of value creation at the sub-national level are harder to find, despite potential some analysis of individual states and counties (NREL, 2013). One example is an assessment for the U.S. state of North Dakota, where direct employment in the RET industry amounted to 1 183 jobs, and indirect employment to 2 840 jobs, in 2011 (Coon *et al.*, 2012). Such disaggregated data can be useful to build public support in the state. A German study offers an example for estimating regionalised employment effects in a consistent framework. In it, direct effects of the production

TABLE 1.6 ADVANTAGES AND DISADVANTAGES OF INVOLVING LOCAL ACTORS FROM AN RET INVESTOR'S PERSPECTIVE

POTENTIAL ADVANTAGES	POTENTIAL DISADVANTAGES
» Familiarity with local circumstances » Lower transport costs » Lower transaction costs associated with international contracts » Higher social acceptance » Higher sustainability » Better suitability to local conditions	» Possibly inadequate certification of professional titles or academic degrees » Insufficient skills availability » Longer lead times » Learning curve

Source: Based on (Dii, 2013)

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[10] *The German federal government has published a non-binding agreement with all German transmission system operators on basic elements of citizen participation (BMU, 2013b), following the establishment of a first "citizens line" with citizen co-ownership through a German grid operator. The aim is to increase public acceptance of grid expansion for RET deployment (Tennet, 2013).*

of facilities and components have been analysed by means of company surveys and other data sources (BMU, 2012).

Impacts across energy consumers and tax payers. The additional costs or benefits that arise from having an energy system based on renewable sources compared with conventional sources need to be allocated across different actors. Some benefit while others bear the burden, depending on a country's individual policy framework. Additional costs may be borne by tax payers or final electricity consumers. For example, feed-in-tariffs in several countries are paid by final electricity consumers, with some paying more than others.

In Germany, the operators of renewable energy plants received about USD 19 billion from most electricity customers in 2012. Major exceptions from these payments included some 700 power-intensive companies and railways, which benefitted from a reduced burden totalling about USD 3.37 billion (BMU, 2013a), due to policies aimed at keeping these industries competitive internationally. Politically, the challenge is in finding a form of burden sharing that meets all relevant policy objectives while being acceptable to all stakeholders.

From another perspective, fiscal impacts refer to the distribution of tax revenues and charges associated with RET installations to different government bodies, such as the municipal, regional or federal level. The sources of those tax payments can be individuals or businesses that own RET installations. Since tax rates and other regulatory details vary significantly across countries, any analysis must take into account the national and local specificities. Similarly, fiscal impacts may include the distribution of RET subsidies across government bodies. In Mexico, total tax revenues from a scenario of 12 GW of wind power deployed by 2020 are estimated at USD 1.1 billion[11], including USD 0.54 billion of income tax (AMDEE, 2012a).

From the perspective of a municipality, it is instrumental to learn how much tax revenue can be expected from having wind or solar plants installed. For example, an analysis of tax revenues associated with RETs for German municipalities concluded that a typical 2 MW wind turbine with an investment cost of USD 3.4 million could generate total tax payments to the municipality of up to about USD 414 000 during the turbine's lifetime of 20 years. In reality, it is more common that value creation is distributed across several municipalities – with some project phases or components situated locally, The exact payments depend on which parts of the life cycle and value chain are actually located within the community (Mühlenhoff, 2010; Hirschl *et al.*, 2010).

Box 1.13

COMMUNITY OWNERSHIP

"Community ownership" has no commonly agreed upon definition; it covers RET projects that are completely in the hands of a community, and those that are only partially community owned ("co-ownership"). Different legal and financial models of community ownership include co-operatives, community charities, development trusts and shares owned by a local community organisation (Walker, 2008). A working group of the World Wind Energy Association proposes the following definition for "community power" (WWEA, 2011):

> "A project can be defined as Community Power if at least two of the following three criteria are fulfilled:
> 1. Local stakeholders own the majority or all of a project [...]

> 2. Voting control rests with the community-based organization [...]
> 3. The majority of social and economic benefits are distributed locally".

Among the different types of ownership structure, co-operatives figure prominently. Such member-based organisations played a major role in the history of electrification in the United States (ILO, 2013). Currently, the European Union (EU) is experiencing a strengthening of energy co-operatives. In developing countries, rural co-operatives often provide access to off-grid electrification (IRENA, 2012a).

[11]   *Exchange rate of 1 MXN = 0.077 USD*

Energy system-related variables

Several energy system-related variables reflect the additional costs or benefits of having a renewable energy-based system compared to a system based on conventional power generation.

Additional generation and balancing costs refer to all costs related to electricity generation from RET, including installation and O&M which occur when RETs replace conventional plants. They can be calculated as the difference between the levelised costs of electricity from the different technologies, even if this approach can be overly simplistic and may not adequately consider issues such as the merit-order effect. Balancing costs refer to the need for balancing intermittent generation from renewables in the short run to ensure system stability, and for providing sufficient firm generation capacity in the long run to ensure security of supply in times of peak demand.

Additional grid and transaction costs include the costs of extending, reinforcing or technologically upgrading grids associated with RET deployment. Such costs may occur at the level of distribution or transmission grids. Transaction costs refer to RET-induced costs between market participants, such as forecasting, contracting, etc., as well as to policy implementation costs, due to, for example, reporting and monitoring obligations.

Externalities occur when human activities (here related to the energy system) affect third parties' production or consumption possibilities without compensating for such impacts. They can be positive or negative, and they arise outside the market system (Verbruggen *et al.*, 2011). Therefore, these effects are not accounted for in the system of national accounts described in Section 1.2.1, as the latter is based primarily on market prices while externalities are, by definition, not priced. RET deployment has the potential to avoid negative environmental externalities that otherwise would be incurred through conventional energy sources.

Decision makers can opt to internalise these externalities as a way to support renewable energy deployment. One mechanism to capture and internalise a specific externality such as climate change, is through the social cost of carbon. It entails establishing a cap on CO_2 emissions and trading emission allowances in a system such as the European Emission Trading System. The resulting price on CO_2 is intended to influence the decisions of companies and consumers in the economy. Outside the OECD member states, a number of countries such as South Korea and China are considering or implementing an emission trading system. In China, several cities and provinces are launching pilot schemes, with the overall aim of setting up a national scheme by 2015. The first emission trading system was officially launched in the city of Shenzhen in mid-2013 (Fei, 2013). Kazakhstan has the only other nationwide scheme in force outside of the OECD; its pilot phase started at the beginning of 2013 (Ecofys and World Bank, 2013).

In addition to environmental externalities, there are other positive externalities associated with RET deployment. In particular, RET may involve technological learning and related spill-over effects on other technologies or other sectors. When new technologies are created and adopted, they often come with benefits for society as whole which are not fully reflected in the prices that the innovating firms can demand in the market (Mitchell *et al.*, 2011). This is especially true if an enabling R&D policy framework is put in place, as discussed in Chapter 2.

Additional effects

Additional effects cover all remaining benefits and costs that may be associated with RET deployment. These effects are not less important than the previous ones, but because they can be classified in more than one of the other categories (*e.g.*, macroeconomic effects and externalities at the same time), they have been placed in a separate category to minimise double counting. One example is effects related to risk reduction.

Risk reduction. RET deployment can contribute to a reduction of accidents or of technical, geopolitical or financial risks, amongst others.

When looking at all energy technologies available, potential risks include oil spills (for example, Deepwater Horizon in 2010), nuclear accidents (for example, Fukushima in 2011), induced seismicity, hazardous substances, long-term storage of nuclear waste, proliferation, terrorist threats and related fatalities. Amongst all energy technologies in use today, RETs are generally

associated with the lowest risk in terms of number of fatalities due to their decentralised nature and limited potential for disasters (Sathaye *et al.*, 2011).

The technical risk (which could also be considered within the "energy system-related effects" category) refers to the possible risk of supply disruptions caused by technical issues, in many occasions caused by the power or gas transport and distribution networks. Since renewable energy is by nature less centralised, it can be argued that RETs reduce these risks. However, electricity generation from variable renewable energy sources is not fully reliable due to the intermittent nature of renewables, and countries are also subject to risks related to dependence on imported renewable energy technology and expertise.

The geopolitical risk is closely related to energy imports. By reducing energy imports, countries can achieve greater independence and avoid potential supply disruptions (for example, in case of conflicts), high energy prices and price fluctuations. Creating an energy system that is more robust against these technical and geopolitical disturbances is usually discussed under the heading of "security of energy supply" or "energy security" (Sathaye *et al.*, 2011). However, this risk is also applicable for countries that are highly dependent on imported RET equipment, components or raw material that would be used for domestic production.

Financial risks are closely related to trade balance issues (included within the "macroeconomic effects" category). They refer to the fact that an economy's high dependence on fossil fuels poses the risk of uncertain future prices, for both importers and exporters, along with the associated financial risk of price volatility. These can affect issues such as costs of finance or investment decisions, which in turn could lead to other negative effects. The fact that renewable energy sources have more predictable costs (for example, the associated fuel costs are relatively low) can mitigate these risks.

1.4 CONCLUSIONS

The socio-economic benefits of renewable energy technologies are increasingly driving their adoption. Renewable energy deployment has the potential to increase income, improve trade balance,

and contribute to industrial development and job creation. However, analytical work and empirical evidence on the topic is needed. This is necessary for a better understanding of the value that can be created from renewable energy deployment, as it can inform policy decisions towards maximising its benefits.

The conceptual framework presented in this chapter is adapted from the existing literature and ongoing research and it can be used to analyse the socio-economic effects of large-scale solar and wind energy deployment. It classifies these effects as macroeconomic, distributional, energy sector and other cross-sectoral (additional). As part of the macroeconomic effects, value added, gross domestic product, welfare and employment are the variables selected in this study to measure value created in the sector. Since renewable energy cuts across many other sectors, and the definition of those sectors varies among countries, the assessment of value creation must be conducted across the different segments of the solar and wind energy value chains.

Opportunities for value creation exist in each segment of the value chain, including project planning, manufacturing, installation, grid connection, O&M and decommissioning. Value creation varies along the different segments of the value chain of solar and wind. In the planning segment, for instance, the bulk of the value is created by engaging specialised individuals and companies to conduct resource assessments, feasibility studies, legal activities, etc. In manufacturing, value can be created in the sourcing of raw material, manufacturing sub-component, and assembling parts. The presence of other industries with similar processes can facilitate the development of a local solar and wind industry; the steel or the automotive industry for wind, semi-conductor for PV and glass for CSP. The value created in the installation phase arises mostly from labour-intensive activities involving civil engineering infrastructure works and assembling of wind or solar plants. These are typically carried out by local Engineering, Procurement and Construction (EPC) companies, unless equipment is imported in which case manufacturers often are responsible for installation activities. The grid connection stage involves the

engagement of highly-skilled grid operators responsible for integrating renewable generation as well as of local companies to undertake any infrastructure development to facilitate grid connection. O&M is a long-term activity that offers opportunities for domestic value creation for all countries, independent of their local renewable energy technology manufacturing capabilities. Finally, the decommissioning of RET plants at the end of their lifespan can comprise recycling as well as disposal or reselling of components. Value is created in related recycling industries, demolition activities, and refurbishing of equipment for sale to new markets.

Further opportunities for value creation can be found in the supporting processes which complement the life cycle of wind and solar energy projects, such as policy-making, financial services, education, research and development and consulting.

The extent to which domestic value is created along the different segments will depend on the overall level of development of a country's renewable energy sector. Countries at the beginning of renewable energy development have a medium-to-high potential for domestic value creation in activities such as O&M, or grid connection. In the case where the country produces technology locally, many more opportunities for domestic value creation arise with the development of a local industry.. As the industry develops, value creation increases along all segments of the value chain if the technology is produced locally and not imported. As the industry matures, activity picks up in areas such as R&D and consulting. When projects reach their end-of-life, value is created in the dismantling segment as well. The potential for policy-making remains high throughout all levels of development of the sector, as policies should be continuously monitored and adapted to changing market conditions.

2 Enabling Socio-economic Value Creation

Value creation from renewable energy deployment spans a vast array of socio-economic effects. The previous chapter presented these effects, and the variables that can be used to assess them, as part of a broader conceptual framework. It also presented the value chain concept that is used to analyse the potential for value creation that exists at each segment of the value chain, as the renewable energy industry cuts across different economic sectors.

A broad range of policies can affect value creation from deployment of large-scale solar and wind energy. It covers policies to stimulate deployment, as well as those aimed at building a domestic industry, encouraging investment and technology transfer, strengthening capabilities, promoting education and training and research and innovation. Identifying the relevant policy areas requires looking at the different segments of the value chain, where the potential for value creation exists and identifying challenges that can hinder value creation.

Policies to support deployment are essential market-creating measures, as they trigger investments into the sector. Depending on the type of deployment policy adopted, the extent of value creation can vary along the different segments of the value chain. The success of deployment policies in creating value also depends on the existence of other complementary instruments, such as those that aim to develop a local industry.

Creating value through local content requires additional support policies that are aimed at ensuring the demand for local products and services, developing domestic production capacity to meet that demand, and strengthening the capacity of firms (and the sector) to ensure quality and efficiency. In addition, policies are needed to create an environment that fosters
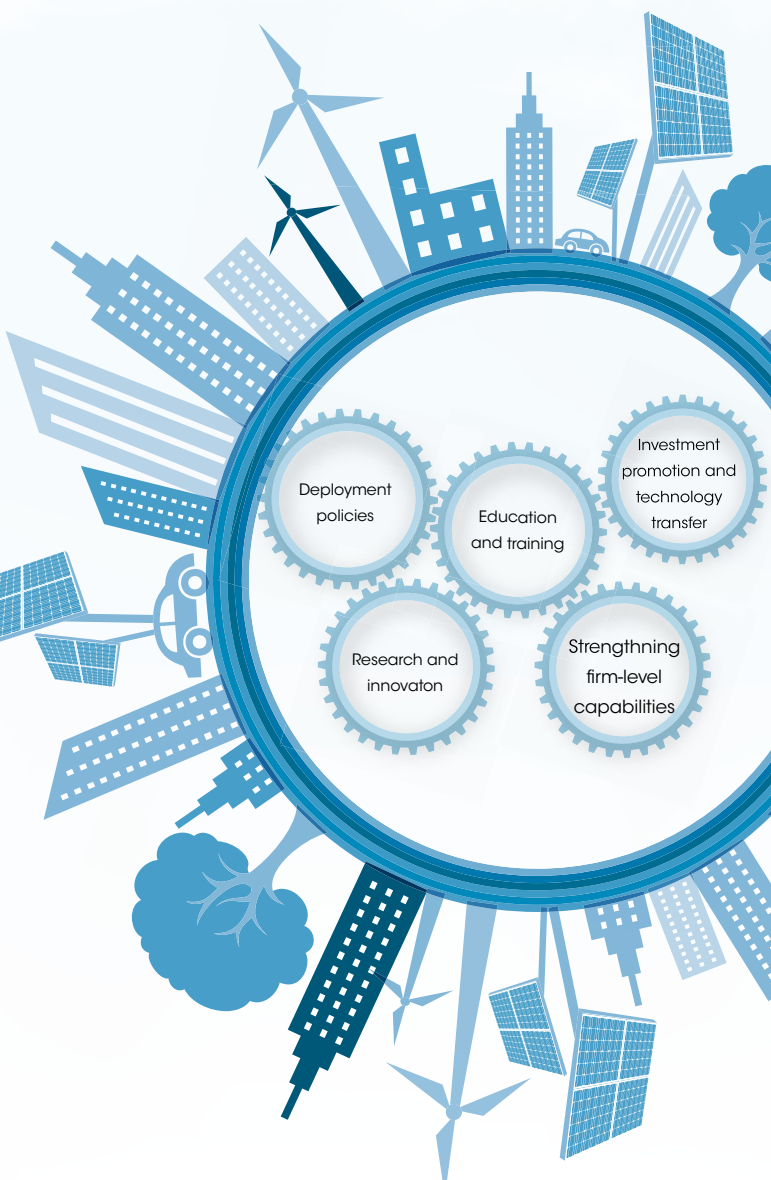
innovation through R&D. Such value creation efforts require the availability of a qualified workforce to meet the diverse skills needed to support a growing renewable energy sector. Moreover, instruments that aim to facilitate access to financing are vital for value creation. All of these policies contribute to the formulation of a tailored policy mix that entails coordination between deployment and the other interacting policies. Some are specific to one segment, such as local production and manufacturing, others are cross-cutting along all segments, such as education and training policies and investment policies.

This chapter presents an overview of different policies and their possible impact on value creation. It covers deployment policies as well as those aimed at promoting investment and technology transfer, strengthening firm level capabilities and building a domestic industry and promoting R&D. It then discusses the key considerations required to ensure the choice of the right policy mix that can maximise the socio-economic benefits of large-scale solar and wind energy deployment. The chapter draws on practical lessons from several country case studies.

2.1 DEPLOYMENT POLICIES

Deployment policies have been instrumental in stimulating market development by creating demand for RETs. These policies are needed to overcome market failures, which include 1) unaccounted externalities related to environmental impacts and security of supply; 2) high costs associated with risks of failure of new businesses; 3) limitations regarding the entry of new players in the market; and 4) difficulty in identifying opportunities for production that exploit comparative

advantages given the dynamic costs and knowledge spill-overs of technologies (IEA-RETD, 2014, forthcoming). Deployment policies play an important role in triggering investments in the sector and thus lead to value creation.

A variety of deployment policies have been adopted worldwide at a regional, national, state or provincial level in support of renewable energy for heating/cooling, transportation and electricity (see Table 2.1). This section of the report focuses on policies to promote renewable energy-based electricity. These policies enable investments and increase installations, leading to value creation directly within the sector (along the value chain of the adopted RET) as well as to indirect effects which are achieved in other sectors. The section discusses different ways in which the type and design of deployment policies can affect value creation.

2.1.1 Policies supporting deployment

Governments worldwide have enacted a variety of policy instruments and targets to mandate or promote the deployment of renewable energy. These can be classified broadly as regulatory policies and targets, fiscal incentives and public financing.

Regulatory policies and targets

Renewable Portfolio Standards (RPS) and quotas. In the case of RPS and quota policies, producers (or distributors/consumers) are required to source a certain percentage of their electricity from renewable energy. This presents an incentive to invest in renewables, either directly by investing in projects or plants or indirectly by purchasing tradable green certificates from other generators. Although technology-specific support can

TABLE 2.1 NUMBER OF COUNTRIES ENACTING SPECIFIC RENEWABLE ENERGY SUPPORT POLICIES AS OF EARLY 2014

	POLICY TYPE	NUMBER OF COUNTRIES
Fiscal Incentives	Tax reduction	91
Regulatory policies and targets	Renewable portfolio standard	29
	Renewable heat obligation/mandate	19
	Biofuel obligation/mandate	58
	Feed-in tariffs[a]	68
	Net metering	42
Public financing	Auctions/tenders	55

[a] Includes feed-in premiums.
Source: REN21, 2014.

be provided through designated technology quotas, these instruments are generally technology neutral and aim to promote the most cost-efficient technology options (IEA, 2008). Such policies have been introduced, either at the national or state/provincial level, in more than 86 jurisdictions, mostly in high- and upper middle-income countries. RPS and quota policies are more prominent on the sub-national level (REN21, 2012, 2013, 2014).

Feed-in tariffs (FiTs) and feed-in premiums (FiPs). These are the most popular type of policy, especially in high- and upper-middle income countries. Under such policies, eligible renewable electricity generators are guaranteed a standard purchasing price or an additional premium price for the electricity they produce, and are normally guaranteed priority dispatch. FiTs and FiPs played a major role in the realisation of approximately 75% of solar PV capacity and 45% of wind development globally as of 2008 (DBCCA, 2010). FiTs and FiPs had been adopted by 68 national governments as of early 2014 (REN21, 2014).

Fiscal incentives and public financing

A variety of fiscal incentives and public financing measures can be applied to encourage private investment in renewable energy. They include tax exemptions or reductions, public investments, capital subsidies, investment or production tax credits and energy production payments.

Tax exemptions or reductions are generally used as supplementary support policies. Renewable energy project developers and electricity generators are exempted from taxes (or a portion of taxes) in order to facilitate the creation of a level playing field with the conventional energy sector. Tax reductions had been adopted by 91 countries worldwide as of 2014 (REN21, 2014). Reductions of import, value-added or sales taxes are most effective in countries with relatively considerable tax rates. They are especially important in lower-middle and low-income countries, many of which depend heavily on imported RET equipment, especially in the early stage of renewable energy sector development.

Capital subsidies, grants (or soft loans) and rebates are used by more than 58 countries worldwide (REN21, 2014). They are different types of monetary assistance from the government, usually to the private sector, to cover a percentage or specified amount of the investment cost of a renewable energy system or service. They aim to help reduce system investment costs associated with

developing renewable energy projects and purchasing equipment. They can also be used to facilitate access to finance through concessional loans for renewable energy projects (IRENA, 2012b).

Auction schemes involve governments announcing bids to install a certain capacity, or produce a certain quantity, of renewable-based electricity. Project developers submit offers which are evaluated based on selected criteria, including the price per unit of electricity. Selected bidders typically enter into power purchase agreements. Auctions can be technology specific, allowing for the promotion of certain technologies and diversification of the country's energy portfolio. They can also be technology neutral, designed to promote the most cost-competitive technology. The design of auctions allows governments to consider other national priorities, such as the development of a domestic industry through local content requirements, which allows for value creation in different segments of the value chain. The number of countries relying on auctions has risen from just 9 in 2009 to 55 by early 2014 (IRENA, 2013b; REN21, 2014).

2.1.2 Value creation through deployment

The extent to which value is created varies depending on the policy instrument. Deployment policies lead to the development of renewable energy projects that can create economic value in terms of environmental impacts (reduced emissions), energy security and economic activity (jobs, income, etc.), but they also contribute to other positive outcomes. For instance, FITs aim to provide secure income streams, increasing the attractiveness of investing in emerging technologies which are not yet competitive. This further generates spill-over effects of R&D of nascent technologies.

Depending on the type of deployment policy adopted, the value created can vary in intensity along the different segments of the value chain. For instance, tax reductions can enable value creation especially in installation and O&M, while auction schemes coupled with domestic content requirements can support the development of upstream supply chain segments. However, this is not to suggest that certain deployment policies are more effective in creating value than others in a specific segment of- or in the entire- value chain. In fact, the same type of policy can affect value creation differently according to its design characteristics and the way in which it is implemented.

Policy design

The design of a deployment policy can influence the specific segments of the value chain where value creation is concentrated, as well as its extent. For instance, technology-specific instruments enable the introduction of new technologies contributing to diversifying the energy mix and hence reducing risks associated with the reliability of the energy system. In addition, this can help stimulate technological development and learning-by-doing, contributing to the creation of a local industry for that specific technology. Technology-neutral instruments can help identify the most cost-effective technology available that could help facilitate a scale-up in its deployment, along with the associated value creation. As such, technology-neutral instruments entail lower support costs than technology-specific instruments.

Another essential design characteristic that can influence value creation from solar and wind energy deployment is the integration of local content requirements within deployment policies. Such measures can allow policy makers to target specific socio-economic benefits and create value in line with their national priorities, such as employment or the development of a local industry. Local content requirements will be discussed in more detail in the following section.

It should be noted that policy design characteristics should be tailored to local market conditions and to the level of maturity of the RET supported. Experience has shown that instruments that have been successful in supporting the domestic renewable energy sector in one country have failed to do so in others, despite a broadly similar country context. An often-cited comparison is between the U.K., Danish, German and Spanish wind sectors in the 1990s (Gross and Heptonstall, 2010; Mitchell, 1996). All four countries had nascent wind sectors as well as an industrial base in equipment manufacturing. Yet the pressures created by the British Non-Fossil Fuels Obligation, combined with a degree of first-mover advantage for Danish, German and Spanish wind suppliers, militated against the use of locally manufactured equipment in U.K. developments (see Box 2.1) (Mitchell, 1996).

Box 2.1

THE IMPACT OF POLICY DESIGN ON THE DEVELOPMENT OF THE U.K. AND EUROPEAN WIND INDUSTRIES IN THE 1990s

The United Kingdom's Non-Fossil Fuel Obligation (NFFO) was established in 1990, and successive rounds of capacity auctions were carried out where developers were invited to submit competitive tenders for NFFO contracts (Gross and Heptonstall, 2010; Mitchell and Connor, 2004).

The NFFO had a complex auction process with uncertain remuneration levels for successful bids, which – together with perceived financial risks of renewables – deterred small and emerging developers from participating. Furthermore, the lack of a penalty for non-completion of NFFO contracts created a perverse incentive for larger companies to bid for additional contracts to stifle the competition. Most NFFO projects were developed by subsidiaries of major utility companies. In addition, the uncertainty of subsidy levels and short subsidy periods compelled successful developers to minimise technological and supply chain risks. Most projects thus used commercially proven wind turbines from established foreign companies with significant existing manufacturing capacity.

Despite the stated aim to "encourage an internationally competitive renewables supply industry" (Charles Wardle, then Under Secretary of State for Industry and Energy, quoted in Mitchell (1996)), the NFFO actually discouraged participation of the U.K.'s emerging wind industry, at the level of both project development and equipment production (Gross and Heptonstall, 2010; Mitchell, 1996). An additional difficulty of the NFFO was that the successive rounds of auctions provoked "rushes" on locations with the highest wind speeds, often the most scenic areas. This exacerbated public opposition to proposed wind farms, creating significant barriers to the acquisition of planning consent (ibid.).

In contrast, the German, Danish and Spanish governments provided targeted support for renewable technologies through fixed-price premiums (Mitchell, 1996; Gross and Heptonstall, 2010). These were more attractive to small and/or emerging domestic developers, manufacturers and investors, having a lower administrative burden and pre-defined subsidy revenues. The resultant presence of local "stakeholder investors" is thought to have contributed to low levels of planning opposition experienced in Germany and Denmark (Krohn and Damborg, 1999; Gross and Heptonstall, 2010). The supportive investment environment created in those countries facilitated the development of a domestic wind industry, which was consequently better-equipped to respond to riskier investment opportunities abroad, such as NFFO in the U.K.

Policy implementation

While the design of deployment policies is one important determinant of value creation, their effective implementation is another. As with any other policy, value creation from deployment policies benefits greatly from a policy environment that is stable and predictable, yet adaptable to dynamic market conditions. Such an environment provides the impetus necessary to attract investments, develop expertise and technologies, and upgrade existing capacities to build a competitive domestic industry and maximise associated value creation.

Country experiences amply demonstrate the importance of policy stability in ensuring a sustainable and smooth expansion of the renewable energy sector, and the arising socio-economic benefits. In Spain, for instance, a scale-back in FiT support (at times retroactively) in recent years has led to a significant dip in solar installations and the closure of a large number of solar panel manufacturing plants (KPMG International, 2012). The socio-economic effect of such policy action, further compounded by the economic environment, was the loss of over 20 000 jobs in the solar PV industry and 14 000 jobs in the wind industry after 2008 (IRENA, 2013a). Box 2.2 discusses some of the lessons learned from recent boom-bust cycles in the PV industry.

Similarly, policy uncertainty associated with extension of the Production Tax Credit for wind energy in the United States has led to abrupt increases and decreases in annual deployment levels. This has had direct effects on value creation in the sector. When it seemed that the Production Tax Credit might not be extended at the end of 2012, analysts warned that wind jobs in the country could decline from 75 000 to 41 000. By contrast, a multi-year extension could allow the expansion to 95 000 jobs by 2016 (AWEA, 2013; Navigant Consulting, 2011).

Box 2.2

BOOM-BUST CYCLES IN SOLAR PV

Several countries have observed PV bubbles provoked by FiTs that were either over-generous or insufficiently responsive to market developments, especially the rapid decrease in costs and the global overcapacity that have been observed in solar PV in recent years.

PV-producing companies have been subject to a dynamic environment of evolving policies globally, with fierce international competition. Global overcapacity in PV manufacturing has put additional strains on European and U.S. manufacturers, resulting in several companies laying off employees. Some declared bankruptcy or were taken over by other companies – including Q-cells, Solar Millenium, Solar Trust, Konarka, Solarhybrid, Nova Solar, Evergreen Solar and SpectraWatt (Hopwood, 2013).

Europe and the United States together manufactured only around 14% of PV modules globally in 2012, down from 17% in 2011 and 43% in 2007. This is indicative of the shift in manufacturing towards countries in Asia that often benefit from significant public support, enabling them to be the source of 86% of global solar module production in 2012 (Mehta, 2013). In order to remain competitive, European and U.S. manufacturers have demanded that anti-dumping tariffs be imposed on Asian manufacturers. In 2012, tariffs were imposed in the United States, while the EU agreed on minimum price and volume limits for PV imports (IRENA, 2013a).

The impacts of such measures on value creation along different segments of the value chain (manufacturing and installation, for instance) are diverse and contradictory. A higher price of imported PV could increase the opportunity for value creation in local manufacturing, but it could potentially decrease the opportunity for value creation in the installation and O&M phases, as well as in manufacturing of the exporting country.

European importers of PV panels state that import duties of as little as 15% could decrease demand for solar panels by 85% (Dalton, 2013). However, a broader look at the industry reveals that almost 70% of the PV value chain lies within Europe. The value added of EU suppliers of capital goods and raw materials, as well as of installers and other downstream businesses, amounts to a combined EUR 40 billion (USD 53.2 billion), with many thousands of jobs (AFASE, 2013).

As a modular and quick-to-install technology, solar PV is particularly responsive to changes in the market environment and hence is prone to boom-and-bust cycles. This underlines the importance of a forward-looking FiT regulation that enables tariffs to be adjusted quickly to technological and market developments in a predictable fashion (Mitchell, 2011).

The success of deployment policies in enabling value creation does not only require their implementation in an ongoing stable manner; they also should be accompanied by vision and objectives, as part of a forward-looking strategy and comprehensive action plan. The accompanying required policy measures, such as developing a strategy based on barrier and impact analysis and coherent policy-making and implementation, are sometimes neglected by countries that adopt deployment policy instruments (IEA-RETD, 2014, forthcoming). It is therefore necessary that the entire spectrum of policies be considered to design and implement the right policy mix. A relevant example for a strategic approach to deploying renewable energy sector as part of a holistic strategy is the case of Mexico (see Box 2.3).

2.2 LOCAL CONTENT REQUIREMENTS

With increasing competition on the global renewable energy market, developed and developing countries with yet-uncompetitive renewable energy industries are increasingly implementing local content requirements (LCRs), which are generally tied to deployment policies such as FITs and auctions (see Section 2.1). These policy measures are introduced to support the development of a nascent industry by ensuring demand for locally sourced equipment and services in an effort to maximise the value created.

2.2.1 Policies promoting local content

Local content requirements require foreign or domestic investors/developers to source a certain share of equipment or a portion of overall costs from local manufacturers or producers. They can be designed and implemented in different ways depending on the broader policy objectives they intend to fulfil.

Objectives guiding local content requirements

The design of local content requirements allows governments to target specific socio-economic benefits in line with their national priorities. For example, LCRs could target job creation by specifying a minimum percentage of locally hired workers, or they could intend to trigger the development of a local industry by requiring the domestic sourcing of specific components or services such as domestic financing. Box 2.4 presents the case of auctions in South Africa, which clearly demonstrates the inclusion of national priorities in the design and implementation of auctions.

Box 2.3

MEXICO'S STRATEGY TO DEPLOY RENEWABLE ENERGY

The structure of the Mexican energy sector has been characterised by the strong participation of the government, led by the Ministry of Energy through the Federal Electricity Commission. Over the last few years, policy makers have collaborated to overcome several significant barriers that have impeded the deployment of renewables, resulting in favourable changes in legislation, including the Law for Use of Renewable Energy and Finance of the Energy Transition (DOF Mexico, 2008) and the Law for Climate Change (DOF Mexico, 2012).

Among the outcomes were:
» Setting a target to generate 35% of electricity from clean energy sources by 2024 (up from 16% in 2011), without specifying the specific technologies and amounts required to accomplish this; and
» Approval of an energy reform that provides the basis for increased private sector participation in power generation.

To achieve these objectives, the government has put in place different instruments aimed at strengthening value chains and increasing participation of the private sector. These include tax incentives, grid connection for permit holders and accounting for externalities in cost-based planning processes. Moreover, over-production is sold to the Federal Electricity Commission at 85% of its value, which is important for reducing risk for the investors in the sector.

As a result, Mexico's renewable energy industry received approximately USD 7.34 billion in investments between 2003 and 2012, mainly in the states of Oaxaca and Baja California. The main investor countries were Spain, the United States, Denmark and France. Both project developers and equipment suppliers are present in the country, and several local manufacturing facilities now exist for wind and PV components.

DESIGN CHARACTERISTICS OF AUCTIONS IN SOUTH AFRICA

The Renewable Energy Independent Power Producer Procurement Programme, South Africa's flagship deployment policy, seeks explicitly to maximise economic value from renewable energy deployment. Since the programme is also aligned with the overarching social goals of the South African government, extensive "non-price" criteria are considered in the assessment process. In particular, the Department of Energy assesses seven socio-economic factors: job creation (weighting: 25%), local content (25%), ownership (15%), socio-economic development (the need of the communities surrounding the project site (15%), preferential procurement (10%), management control (5%) and enterprise development (5%). Each factor has a minimum requirement and also a target value, both of which increase with each successive bid round.

Job creation is considered a major component of the assessment criteria and is aligned closely with the government's policy to tackle unemployment, poverty and inequality. The government is pursuing the job creation agenda in two different ways: first, bidders are required to indicate certain statistics such as the percentage of South African nationals, marginalised social groups and people from local communities employed in the project company. Second, increased local production is required, which is defined with respect to the capital costs and costs of services procured for the construction of the facility (without violating the rules of the World Trade Organization).

As part of the other criteria for evaluation, the process requires the bids to demonstrate a South African entity participation level of 40% as well as setting certain thresholds on the actual level of certification of the local partners. At the same time, they are required to indicate the percentage of equity owned by marginalised social groups and local communities.

Source: IRENA, 2013b.

Implementation of local content requirements

In meeting the set objectives, different approaches to LCR implementation are being adopted. Table 2.2 provides an overview of selected country experiences in designing and implementing LCRs schemes. In many countries, LCRs are used as a precondition for the receipt of support measures such as FiTs (*e.g.* Ukraine), tax exemptions or infrastructure support. Some countries – including Italy, France, Turkey and Malaysia – offer a premium over regular FiT rates to companies meeting specified requirements. Other countries impose a penalty on companies that fail to meet LCRs. For instance, Croatian legislation plans to penalise companies that fail to meet the set target of 60% by offering them a reduced rate of between 93% and 99% of the full FiT (Kuntze and Moerenhout, 2013).

Local content requirements are generally tied to auctions. They can either be set on a voluntary basis, or as a precondition for bidding. In the first case, they aim to provide bidders with the opportunity to score higher in the tendering process, as the case for Morocco or South Africa. In the second case, project developers are only eligible to bid for an auction if they satisfy the requirements that are set, as the case of Quebec's 2003 wind auction in Canada.

Moreover, LCRs can also be applied as a precondition to receive public financing. For instance, in Brazil, project developers participating in auctions were initially required to get 40% of components from Brazilian suppliers (rising to 60% in 2012) in order to qualify for subsidised loans by the Brazilian Development Bank or Banco Nacional de Desenvolvimento Economico e Social (BNDES). Another example is the case of the auction in South Africa, where foreign banks need to be licensed to conduct regular banking business in the country and all sources of funding must be denominated in local currency. This has resulted in South African banks playing a major role in the country's Independent Power Producer procurement programme (Diemont *et al.*,2012).

In many cases, LCR legislation foresees a gradual increase of the percentage of inputs that needs to be sourced locally over a period of several years. The effects of renewable energy policies with LCRs have been quite different in the countries and provinces where they have been applied (Kuntze and Moerenhout, 2013; Hao *et al.*, 2010).

TABLE 2.2 LOCAL CONTENT REQUIREMENTS BY RET

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

Source IRENA, 2013a

2.2.2 Value creation through local content requirements

Governments adopt LCRs with the aim of creating value by supporting the development of local nascent industries or services, creating employment and/or promoting technology transfer. These impacts can materialise along different segments of the value chain as well as within the supporting services such as the financial sector. However, assessing the impact of LCRs on value creation is difficult, especially in countries where multiple support policies are adopted.

Four determinants may help to analyse the effects of LCRs on local value creation in the countries where they are adopted while minimising market distortions and additional costs for local electricity consumers (Kuntze and Moerenhout, 2013).

» **Market size (both local and regional) and stability are important prerequisites for investors for the development of projects or for the establishment of local manufacturing sites.** They refer, among others, to the resource potential for renewable energy, the amount of government support and the long-term demand for renewable energy projects. Market size and stability are vital as they can attract investors despite the additional cost that LCRs can cause. In small and unstable markets, manufacturing sites will rarely pay off since the economies of scale necessary for cost-effective production cannot be reached (Hao *et al.*, 2010).

» **It is crucial that the share of local content required for an investment is chosen appropriately.** If it is too high, LCRs will demotivate project developers to invest, as local components might be difficult or too expensive to source. Also, a government should take into consideration the country's available production capacities in order to avoid bottlenecks and delays in the realisation. However, if the share is too low, it will not increase local content but potentially only create administrative hurdles. Governments should continuously attempt to monitor the effect of their LCRs in the market and should amend them according to the needs they see to protect certain local industries. Usually, the restrictiveness of LCRs increases over time, as domestic industries are supposed to gain

competitiveness. There are no empirical studies on what an appropriate level of restrictiveness is. Generally, LCRs should be designed carefully with the involvement of different stakeholders (particularly the private sector), and an exit strategy should be included to assure security for investors (IRENA, 2013b).

» **It is important that governments integrate local and international businesses (project developers and component producers) in the design of their LCR scheme.** Governments can learn how to determine appropriate LCR rates, while the local businesses can prepare co-operation with other businesses along the value chain of products and identify their need to protect infant industries from the international market. Local businesses are also an important counterpart and partner for investors, as their know-how can be transferred. For example, the know-how of construction companies could be used for wind turbine installations. Furthermore, the government can test what policy measures may be most appropriate to catalyse local manufacturing.

» **LCRs will only catalyse long-term competitiveness of local businesses if the government incentivises innovation and learning-by-doing.** Businesses will have the chance to become internationally competitive only if they develop the necessary technological capabilities required for learning and for improving efficiency and quality. Further, LCRs should first focus on components or services, for which global competition and market barriers are not too high.

Moreover, the design of LCRs should consider existing areas of expertise along the different segments of the value chain and be directed at those with the highest development potential. For example, developing domestic PV manufacturing capacity can leverage an existing semiconductor-based industry, and similarly, a robust steel and/or cement industry can serve as a base for manufacturing wind components. The case of India (see Box 2.5) provides insights into the challenges of implementing LCRs, focusing on developing upstream manufacturing of a specific technology that could be undermined by using other technology options.

In general, LCRs should be accompanied by other policies aimed at strengthening local firm capabilities, ensuring the availability of skilled labour and facilitating access to finance.

2.3 INVESTMENT PROMOTION AND TECHNOLOGY TRANSFER

Access to finance is among the critical success factors for the development of the renewable energy sector and value creation. As such, investment-promotion mechanisms are being adopted to overcome existing financing barriers and to attract investors into the sector. In the absence of a well-developed local financial market, these mechanisms aim to facilitate foreign investments, including foreign private sector investments. Aside from employment creation and the development of new sectors, the latter may also contribute to technology transfer and the enhancement of domestic capabilities (*e.g.*, in manufacturing,

innovation and R&D). This section explores this dimension of value creation by looking into the role of foreign investments in technology co-operation. It starts with a discussion on different policies that can be adopted to facilitate investment in the sector. This is followed by a discussion on how policy makers can aim towards higher levels of technology transfer and co-operation as a result of increased foreign investments, thereby maximising value creation.

2.3.1 Policies facilitating investment in renewable energy

Investments in the renewable energy sector are necessary to increase deployment. These investments can be directed at different segments of the value chain and come from diverse sources, both domestic and foreign. They include professional investors such as commercial banks, equity firms, insurance companies, pension funds, industry bodies, clean energy

Box 2.5

EXPERIENCES WITH LCRS IN INDIA

In 2010, the Indian government launched an auction scheme with LCRs for solar PV and CSP plants as part of its Jawaharlal Nehru National Solar Mission. In the first round (2010-2011), the scheme required investors to source crystalline silicon modules locally (the LCR did not apply to thin film modules). In the second round (2011-2012), the LCR was extended to crystalline silicon cells.

The Indian auction with LCR has so far had a limited impact on the development of a PV industry. A first reason appears to be that many project developers circumvented the LCR, limited to crystalline silicon components, by using thin film components, which they could source cheaply from abroad. A factor that potentially further increased the attractiveness of using thin film modules was a programme by the U.S. Export-Import Bank that offered cheap loan rates to investors using U.S. thin film technology. In the most recent round of bidding, however, the LCR was made technology neutral for solar, thereby addressing the thin film loophole. The capacity that was tendered was divided into two categories instead:"non-LCR" and "LCR" (MNRE, 2013).

A second reason for the ineffectiveness of the Indian scheme seems to be conflicting government policies and incentives at the regional, state or federal levels. For instance, locally manufactured PV modules and cells were subject to government duties, while imported components were exempted from duties. Due to the exemption of thin film components and to higher duties on local components, it appears questionable that the infant local crystalline silicon manufacturers, which the LCR scheme was meant to support, were protected sufficiently from the international market to become competitive.

The Indian scheme focuses strongly on developing local crystalline silicon module and cell markets; global competition in these markets is very high due to overcapacities and very low prices for PV systems. The government did not, however, attempt to increase the local share in assembly, installation and maintenance of PV projects, although those parts of the value chain of PV projects have significant local content and employment potential. Finally, most local manufacturers in India focus on low-cost assembly of PV components and invest little in R&D and innovation potential.

Source: (Johnson, 2013).

companies and development finance institutions, as well as start-up project developers (IRENA, 2012c). In order to attract investors to the sector, investment-promotion mechanisms are being adopted to overcome existing financing barriers and to increase the financial feasibility of renewable energy projects.

Financing mechanisms that are suitable for renewable energy development depend on country-specific conditions such as the maturity of renewable energy markets, financial market development and the general environment for investment. Financing mechanisms include regulatory and incentive measures that shift investment into renewable energy (banking regulations, reduced interest rates, *etc*.). It also encompasses targeted interventions that aim to maximise the leverage of additional investment into the sector, which can be achieved by addressing existing investment barriers. They include guarantees to mitigate lending risk, project debt financing, loan softening programmes, and grants for project development costs. Ample studies discuss the overall financing mechanisms relevant for the renewable energy sector. This section focuses specifically on investment approaches that aim for higher levels of technology transfer, thereby maximising value creation. These include investments from foreign sources, such as development finance institutions and foreign direct investments.

Development finance institutions

Development finance institutions (DFIs) play an important role in directing international funds to local stakeholders, normally through national government agencies or national development banks. DFIs and other public investors (foreign and national) can include in their objectives socio-economic effects in addition to market development. This maximises value creation from renewables beyond financial returns.

Development banks and international donors can finance large-scale renewable power projects in developing countries through multilateral and bilateral official development aid. Examples include the World Bank's Climate Investment Funds and, specifically, the Clean Technology Fund, with commitments of USD 5.5 billion until 2013 (CIF, 2014). As of December 2013, the Clean Technology Fund had approved USD 1.5 billion to support large-scale deployment of renewable energy in 10 middle-income developing

and emerging countries (Chile, Colombia, Egypt, India, Indonesia, Mexico, Morocco, Philippines, South Africa, Thailand, Ukraine). Also, through its Scaling Up Renewable Energy in Low Income Countries Program, it provides support for renewable energy in an additional eighty-six pilot low-income countries (CIF, 2014).

Beyond project-level investments, international finance institutions have contributed to rising investment opportunities for the private sector through large finance portfolios (Atteridge *et al.*, 2009)[12] As discussed earlier, one of the challenges in reaching commercial viability of renewable energy projects is accessing affordable finance for projects, especially those involving new technologies. For instance, the bankability of projects for CSP (parabolic trough) and offshore wind technologies could be lower than for more established technologies, such as solar PV and onshore wind energy. In the case of onshore wind, which has reached grid parity in many locations, the involvement of local banks in the financing process is quite common.

The involvement of local banks has supported renewables deployment in Morocco, although this was not the case for the country's Ouarzazate CSP plant (see Box 2.6). For that project, achieving commercial viability required much higher levels of investment to cover both the high capital costs of risk as well as costs associated with market development for capacity building and infrastructure needs (Falconer and Frisari, 2012). For international financial institutions to channel funds to developing countries in support of renewable energy plans, two factors are critical aside from abundant renewable energy resources: 1) strong government commitment that is materialised in policy certainty, and 2) buy-in from the private sector (nationally and internationally), which can ensure long-term development of the renewables sector.

Foreign direct investment

Foreign direct investment (FDI) is generally channeled through transnational companies. Such investments play an important role in helping the host country enhance value creation with respect to knowledge acquisition, employment creation and upgrading capabilities along the value chain of different RETs. While the effects of FDI cut across the value chain, they may be found especially in project planning, manufacturing, construction and O&M. For example, Dii (2013)

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[12] *UNCTAD (2011) argues that an additional concern with international financing is that these funding sources are "highly fragmented, uncoordinated and lack transparency", with complex financing arrangements.*

INTERACTION BETWEEN INTERNATIONAL DONORS, NATIONAL GOVERNMENTS AND PRIVATE SECTOR INVESTMENTS TO SUPPORT RENEWABLE ENERGY PROJECTS IN MOROCCO

Morocco's 160 MW CSP power plant in Ouarzazate is an example which underlines the importance of international donors and private investment for deploying large-scale renewable energy projects (Falconer and Frisari, 2012). The implementation of Ouarzazate I, with investment costs of approximately USD 850 million, is ensured by a public-private partnership approach with independent power production and a power purchase agreement for 25 years.

To finance the project, the private consortium selected in the tendering process provides 75% of the required equity, and the World Bank's Clean Technology Fund, co-financed by the African Development Bank and European donors (AFD, KfW, EIB, NIF), and provides soft loans of approximately 675 USDmillion for the project. Additionally, the Neighborhood Investment Facility and the International Climate Initiative of the German government support the project through almost USD 34 million in grants as part of the equity share of Morocco's Agency for Solar Energy (MASEN).

estimates that about 1 million jobs may be created in manufacturing, construction and O&M as a result of investments in an integrated EU-MENA power system. To these, additional second-order effects on the larger economy are to be expected. However, the full potential that FDI offers can be harvested only through a proactive approach by the government towards creating an enabling business environment for investors, offering attractive incentives and encouraging investors to maximise local value creation through their operations.

The two main destinations for foreign investment in renewables are 1) financing and building facilities for manufacturing parts and components, such as investment in an inverter factory in South Africa by the German company SMA, and 2) financing electricity generation projects such as the Ouarzazate CSP project in Morocco or the Shams 1 CSP project in Abu Dhabi, United Arab Emirates.

So far, most FDI for manufacturing solar and wind energy parts and components has been concentrated in developed countries (Hanni *et al.*, 2011). However, developing and emerging countries increasingly have attracted investment in such activities – especially countries that offer larger and more stable markets (*e.g.*, China, India, South Africa, Malaysia and Mexico). Between 2003 and 2010, China, India and Malaysia hosted approximately 30% of all renewable energy manufacturing FDI projects (Hanni *et al.* 2011). A similar pattern can be observed with respect to electricity generation projects, although the landscape of host countries is more diverse.
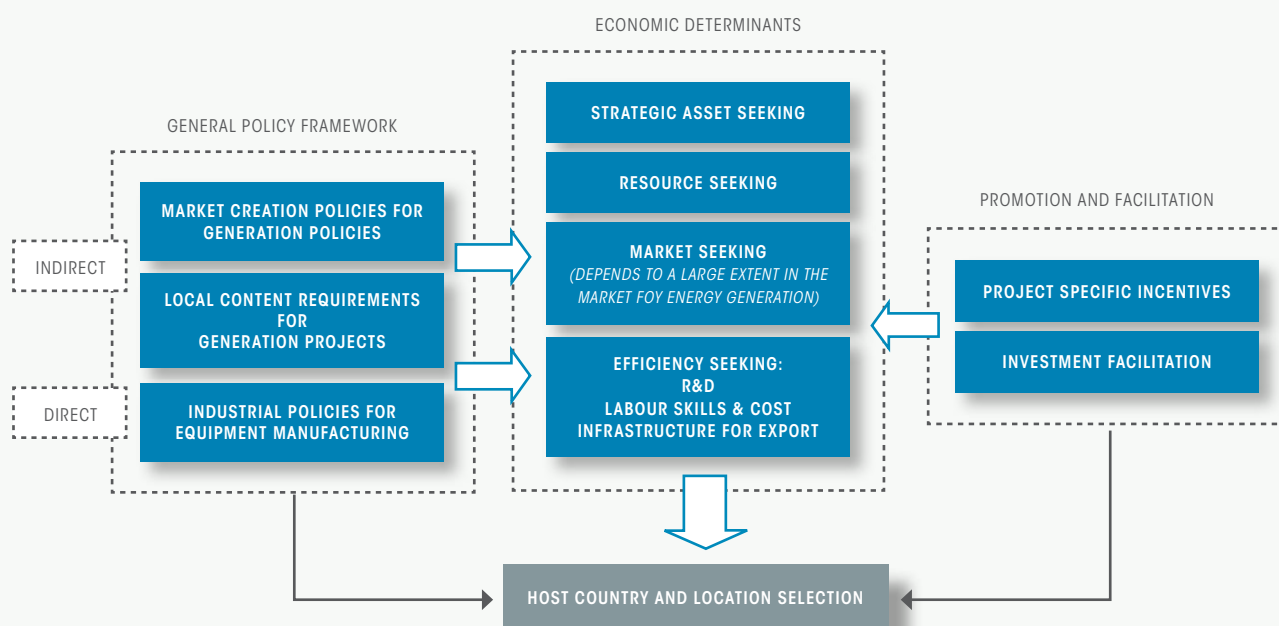
Enabling environment for foreign direct investment

The specific drivers of FDI in renewable energy projects, especially investments in setting up production facilities for parts and components of RET, vary but can be grouped into three main categories, as per UNCTAD (2010) (see Figure 2.1): 1) the general policy framework with respect to market creation policies (*i.e.*, RET deployment policies discussed earlier in Section 2.1), firm-level policies to strengthen capabilities (see Section 2.4), and local content requirements (see Section 2.2); 2) economic determinants referring to the specific drivers for investment and 3) investment promotion and facilitation measures (see below). Other factors include the presence of an educated workforce (see Section 2.5), adequate infrastructure, the rule of law and a functioning bureaucracy (UNCTAD, 2011).

Effective investment promotion and facilitation measures have proved to be critical for attracting FDI to developing countries (World Bank, 2013). To make the most from attracting investment with respect to job creation, technology transfer and private sector development, the governments of developing countries need to be proactive in "strategically targeting, guiding and nudging foreign investors" (IEA-RETD, 2014, forthcoming). Such an approach could lead to a higher level of embeddedness of foreign investors in the productive sector of the host economy, contributing to increased value creation. Examples of strategic investment promotion programmes exist in various countries (see Box 2.7 for a discussion of

ECONOMIC DETERMINANTS

GENERAL POLICY FRAMEWORK

STRATEGIC ASSET SEEKING

RESOURCE SEEKING

PROMOTION AND FACILITATION

MARKET CREATION POLICIES FOR GENERATION POLICIES

INDIRECT

LOCAL CONTENT REQUIREMENTS FOR GENERATION PROJECTS

MARKET SEEKING
(DEPENDS TO A LARGE EXTENT IN THE MARKET FOY ENERGY GENERATION)

PROJECT SPECIFIC INCENTIVES

INVESTMENT FACILITATION

DIRECT

INDUSTRIAL POLICIES FOR EQUIPMENT MANUFACTURING

**EFFICIENCY SEEKING:
R&D
LABOUR SKILLS & COST
INFRASTRUCTURE FOR EXPORT**

HOST COUNTRY AND LOCATION SELECTION

Source: Hanni et al. (2011, 40) based on UNCTAD (2010)

Costa Rica's strategy in the knowledge-based sector). These strategic investment promotion programs have materialised in the set-up of manufacturing facilities for different parts and components and the engagement of local suppliers, which further contributed to spillover effects in the economy. The practical lessons for the renewable energy sector in terms of maximising value creation that can be extracted from the case presented in Box 2.7 are: (1) elaborating a coherent and long-term strategy for developing the sector; (2) offering government commitment to investing in education and training programs; and (3) committing to the support of foreign investors through various services.

Box 2.7

STRATEGIC INVESTMENT POLICY IN COSTA RICA

Recognising the value of a knowledge-based economy and leveraging on the advanced level of education of its population, Costa Rica's government sought to attract foreign investment through a National Strategy for Investment Promotion initiative. The strategy, centred around a technology policy that prioritised the improvement of domestic telecommunication infrastructure, also promoted education focused on information technologies and encouraged technological pilot projects with international corporations. Within this initiative, foreign high-tech firms such as Microsoft, Hewlett-Packard and Boeing were invited to make investments in Costa Rica. This eventually led to a big investment by INTEL, which has committed to invest USD 500 million in a production site for assembling and testing Pentium-II processors.

INTEL offered no major firm-specific concessions when selecting Costa Rica from a number of potential assembly plant sites that included Brazil, Chile, Mexico, the Philippines and Thailand. Costa Rica's focus on an electronics strategy, its willingness to invest in training, and its strong commitment to the INTEL project were the main factors contributing to this choice. The facilitation work undertaken by Costa Rica's investment promotion agency CINDE, as well as the president's personal support for the project, were decisive.

The INTEL production site triggered follow-up investments by suppliers. Subsequently, other large corporations, including Hewlett-Packard, opened a regional service centre for Latin America in Costa Rica.

Source: Spar, 1998

Investment promotion. In some developing countries, investment promotion agencies have shown to offer comprehensive services that include providing relevant statistical information to potential investors, forming partnerships with other investment promotion and domestic institutions and promoting incentives offered (see the examples of Tunisia and Morocco in Box 2.8). Indeed, highly important elements include: (1) strategic targeting at the firm and sector levels (across all elements of the value chain from design to purchasing, production, distribution, services and R&D) (OECD, 2005), (2) establishing partnerships across agencies (government agencies, private sector associations, technical bodies, promotional agencies) for gathering information and effective dissemination, and (3) providing accessibility to investors (World Bank, 2013). The OECD (2005) further adds that "rooting FDI in the host country through good linkages with local suppliers, subcontractors, business partners, technical institutes and universities, etc., and through good facilitation in the post-investment phase" is necessary. An increasing number of studies has been concerned with assessing local manufacturing capabilities along the value chain for solar energy technologies, especially in the MENA context (Gazzo, 2011; GIZ, 2012b; GIZ, 2013; World Bank, 2013). Such studies can inform policy makers about the competitive advantage in these sectors relative to the requirements of international investors, which can then guide investment promotion and facilitation agencies in their effort to attract private sector investors in the specific sector and activities. One of the crucial elements of FDI is the potential for technology and knowledge transfer, which can further add local value within the renewables sector and in industry in general.

2.3.2 Value creation through investment promotion and technology transfer

The opportunities for value creation from promoting investments in the sector are manifold. Aside from the employment creation and the value that results from developing renewable energy projects and manufacturing facilities for components, there is additional potential for value creation in the financial sector itself as well as other opportunities for value creation from the knowledge transferred through foreign investments.

As mentioned earlier, investments can be sourced by local stakeholders or by foreign investors. In the case where the former applies, value is created through

Box 2.8

INVESTMENT PROMOTION AND FACILITATION IN TUNISIA AND MOROCCO

The Tunisian Foreign Investment Promotion Agency (FIPA) was recently highlighted in the World Bank report Global Investment Best Practices in 2012 as a best practice in providing sectoral information. The agency's online content, available in eight languages (Arabic, Chinese, English, French, German, Italian, Japanese and Spanish), provides potential investors with comprehensive decision-relevant information on six selected sectors (food, mechanical, leather and shoes, electronics, information and communicatins technology and textiles).

The website's breadth of information and ease of navigation suggest a deep understanding of investors' information needs and exploration habits. The site provides information on each sector, including data and figures on production, employment and exports, and appraisal of Tunisia's assets. It lists key location advantages, indicates the country's competitiveness in comparison to other potential investment destinations and provides success stories of major investors that currently have a presence in Tunisia. Overall, the online portal allows potential investors to attain a balanced overview of costs and conditions in Tunisia for a specific sector of interest in a relatively short period of time.

The Moroccan Investment Development Agency (AMDI) was established in 2009 as a financially autonomous public institution. More recently, business associations (such as the Fédérations des Chambres Professionelles and the Conféderation Générale des Entreprises du Maroc, CGEM) became part of its board of directors. Like FIPA, AMDI is explicitly mentioned as a best practice by the World Bank (2013), In part for its development of an integrated approach to handling investor inquiries.

Sources: Information on Tunisia from Vidican et al. (2013) based on FIPA-Tunisia (2013) and World Bank (2013). Information on Morocco from Vidican et al. (2013) based on interviews and online materials from AMDI.

the interest earnings, capital appreciation and/or dividends that result from profitable investments. In the case of the latter, although the financial value is generated in the lending country, the local value that is created is the resulting contribution to technology transfer and the enhancement of domestic capabilities (*e.g.,* in manufacturing, innovation and R&D). In some cases, foreign investments are channeled through local institutions which contributes to building the capacity of the local financial sector. This section explores this dimension of value creation by looking into the role of foreign investments in technology and knowledge transfer. Such a process can be guided by firm-level and national-level strategies through linking transnational companies with local small-to-medium enterprises (SMEs), and also at the international/global level through technology co-operation mechanisms.

Technology transfer is important not only for acquiring codified or explicit knowledge (in the form of blueprints, software, equipment), but also for acquiring tacit or intangible knowledge. This is the type of knowledge that comes with practice, that is difficult to measure and that is highly embedded in the process of learning how to use, maintain and adapt certain technologies, broadly defined. Both types of knowledge are essential for enabling technology-acquiring entities to absorb, use and apply technology to various productive purposes. Enhancing domestic technological capabilities is critical for facilitating both the diffusion of existing RETs within host countries and the adaptation of these technologies to the framework conditions in these countries (Ockwell *et al.,* 2010). Hence, in order for technology transfer facilitated through investment to be effective, "it must take place as part of a wider process of technological capability building" in host countries (Ockwell *et al.,* 2007). To this end, various channels for transferring technology are relevant. These include, among others, providing education and training and forming business linkages.

Education and training. One channel for technology transfer is education and training, which is linked to the acquisition of technical equipment, the employment of local workers in international firms, and participation in trade fairs or workshops. Education and training is discussed further in Section 2.5.

Business linkages are one of the formal channels for technology transfer which materialise into joint ventures, partnerships and consortiums, technology licensing programmes, technical assistance programmes or research collaborations. Business linkages (both horizontal through mutually beneficial relationships between businesses at the same level of the value chain and vertical through relationships between businesses from different levels of the chain) have been identified as one of the most effective ways for SMEs to both access more advanced knowledge and enhance their capabilities, enabling them to produce higher value-added goods and services (Altenburg, 2005).

The large-scale production capabilities of transnational corporations, coupled with the flexibility and specialisation of SMEs, allows for successful technology transfer through spill-overs and trickle-down effects, leading to win-win opportunities (Vidican *et al.,* 2013).

Whether foreign investment is geared towards achieving higher technology transfer depends on the strategic approach of the government and on the firm's level of involvement in achieving a higher level of integration in the transfer process. For instance, if foreign investment is not accompanied by the development of local industry and engagement of local suppliers, the level of technology transfer is likely to be limited. An illustrative example is Toyota's decision to manufacture the Prius hybrid vehicle in China but to import all components. This resulted in limited technology transfer (Ockwell *et al.,* 2007).

Outside of large emerging economies, such as China, India and Brazil, few developing countries have engaged in formal mechanisms of technology transfer, such as joint ventures and technology licensing. Although it currently faces market access problems, the Egyptian company SWEG (Sewedy Wind Energy Group) was created as a joint venture with SIAG Schaaf Industrial AG, a German wind tower manufacturer. In 2007, SWEG also licensed technology from a small Spanish technology company, MTorres, for transferring know-how on manufacturing gearless wind turbines. However, the slow development of a sizable local and regional market, due mainly to political instability, has created severe operational

challenges for SWEG and, more generally, for the development of Egypt's wind energy market (see Box 2.9). This example should illustrate to policy makers that long-term visibility/predictability with respect to market development is necessary for capturing value from foreign investment in the form of domestic knowledge creation.

Turkey has also taken a strategic approach to promoting joint ventures with technology companies from the renewable energy sector, in Europe, the United States and East Asia (see Box 2.10). The relatively large local market, good renewable energy resources, stable policies and existing capabilities offer positive signals to potential private sector investors, allowing them to ramp up their activities locally along the life-cycle of RETs.

Another example is that of Morocco, where different mechanisms for technology transfer have been used to support the build-up of domestic capabilities (see Box 2.11). However, the development of the sector in Morocco is in a very early stage, which makes it difficult to assess whether these mechanisms have been effective. Yet, the approaches followed by Nareva Holding in the wind sector by engaging with foreign technology providers in all stages of the wind energy life-cycle, and by AE Photonics in terms of inter-company training for solar water pumps are likely to contribute to value creation in terms of employment and knowledge capabilities upgrading.

The benefits from technology transfer for the host countries are evident. In summary, several aspects should be highlighted for policy makers, as relevant

Box 2.9

TECHNOLOGY TRANSFER IN THE WIND ENERGY SECTOR IN EGYPT

In Egypt, the El-Sewedy Group is the sole company to invest in wind energy through building up knowledge and manufacturing capacity for turbine components, such as cables, transformers, communications and electrical equipment. The company entered the renewable energy sector in 2004 through the creation of the Sewedy Wind Energy Group (SWEG) with financial support from the European Union, and has since grown to include manufacturing and distribution facilities worldwide.

SWEG has established a tower-manufacturing facility, together with the German manufacturer SIAG Schaaf Industries AG. With construction starting in 2008, SWEG's facility has an annual production capacity of 120 steel wind towers and produce internal components like ladders, ducts and platforms. The factory opened in March 2010 and plans call for increasing its annual production capacity to 400 towers. SWEG also plans to develop a turbine and blade factory, utilising local knowledge of fiberglass boat construction in the manufacturing of glass-reinforced plastic blades.

Yet with the global wind-power market looking promising in 2014, SWEG has pressed forward with efforts to acquire cutting edge global technologies. In spite of the clear potential for local wind-energy component manufacturing, investment plans are stalled because of Egypt's economic downturn and political instability. Breaking into export markets, meanwhile can be difficult without having a very strong track record in the domestic market.

SWEG has invested in training, sending engineers abroad to attend courses, as well as developing an in-house course. SWEG personnel and individuals from partner companies in Spain and Germany all have access to training, as SWEG attempts to learn the wind industry's entire value chain. Apart from blades, gearboxes are the components that is most particular to wind technology. SWEG has tried unsuccessfully to form partnerships with leading European wind turbine manufacturers Nordex and Gamesa to acquire the necessary know-how. A smaller lower-profile Spanish company, MTorres, also possessed wind turbine technology, providing an alternative transfer source. In 2007, SWEG acquired a stake (first 30%, then a majority control) in MTorres, as a way of obtaining knowledge to manufacture gearless wind turbines.

Source: Vidican, 2012, 38-41, based on interviews with El-Sewedy (Cairo, October 2011).

ENSURING TECHNOLOGY TRANSFER THROUGH JOINTVENTURES IN TURKEY

Turkey is a good-practice example when it comes to business partnerships in the renewable energy sector that are geared towards technology transfer. Turkey aims to generate 30% of its power from renewables by 2030 and to develop 600 MW of solar PV capacity by 2013. To achieve these targets, specific incentives are offered to trigger the markets for solar and wind. A FiT for renewable energy and an additional payment for locally produced equipment attract many investors to Turkey. The Turkish Energy Ministry is seeking to further increase local content incentives to stimulate investment and local production (Nicola and Parkin, 2013).

To build up production capabilities for solar PV, Turkey fosters technology transfer by promoting joint ventures, aimed at enabling the country to supply the emerging regional market (ISPAT, 2013). For example, the Chinese solar cell and module manufacturer, China Sunergy, and the Turkish solar system provider and project developer, Seul Energy Investment, have set up a solar cell and module manufacturing plant in Turkey. This joint venture not only

creates 1 200 new jobs, but also supports Turkey's efforts to become competitive in the solar energy sector.

German companies also are interested in investing in manufacturing plants in Turkey, as the recent example of Nordex Enerji A.S. Vexco GmbH shows. Several German SMEs plan on investing in solar manufacturing plants, fuelled by high prices in the power market, electricity demand and economic growth (Nicola and Parkin, 2013). Joint ventures with German companies are also being promoted in the wind and hydropower sectors.

Recognising the abundant business opportunities in Turkey's energy sector, the U.S. Commercial Service and the U.S. Embassy in Turkey are acting as a liaison between local companies and potential U.S. suppliers of renewable energy and energy efficiency equipment, services and technologies. Several joint ventures have already been established. The challenge for all these projects, however, is to ensure that technology transfer occurs and increases progressively.

Sources: (Vidican et al., 2013), US Commercial Service in Istanbul (2014) (http://export.gov/california/build/groups/public/@eg_us_ca/documents/webcontent/eg_us_ca_037146.pdf accessed on 14 March 2014); EnBW (2014) (http://www.enbw.com/company/press/press-releases/press-release-details_62466.html, accessed on 14 March 2014)

to not only attracting investment but also for incentivising investors to engage with local suppliers and contributing to the enhancement of knowledge capabilities and other macroeconomic effects. They include: (1) long-term market predictability; (2) presence of (and commitment to develop) domestic knowledge capabilities compatible with the needs of the new sector (*i.e.* wind or solar energy); and (3) favourable conditions in terms of ease of doing business.

2.4 STRENGTHENING FIRM-LEVEL CAPABILITIES

The ability of a firm to acquire, use and adapt technology and therefore maximise value from its activities depends on its "capacity to gain an overview of the technological components on the market, assess their value, select which specific technology is needed, use it, adapt and improve it and finally develop technologies oneself (Meyer-Stamer, 2008). Technological capabilities enable firms to identify

niche market opportunities, to respond to competitive pressures and to position themselves relative to global and regional market dynamics. As discussed earlier, strong knowledge capabilities also contribute to attracting investments and encourage technology transfer. This section discusses policy measures that can be adopted to promote the development of capabilities of local firms as well as their contribution to value creation.

2.4.1 Policies promoting the development of local capabilities

Various programmes and policies can be strategically targeted towards enhancing capabilities in the private sector, such as industrial upgrading programmes, supplier development programmes and the development of industrial clusters that promote competition and co-operation across a range of stakeholders. These cross-cutting policy interventions may result not only in GDP growth, but also in higher employment, welfare and improved private sector competitiveness.

Industrial upgrading programmes

Industrial upgrading refers to "the process by which economic actors – nations, firms, and workers – move from low-value to relatively high-value activities in global production networks" (Gereffi, 2005). For export-oriented countries such as China and Mexico, one can assess industrial upgrading by identifying shifts in the technology content of their exports over time.

Policies in support of specific upgrading programmes exist in several countries at the national or regional level. The proper targeting of these programmes to the specific needs of the sector and specific types of companies is critical for the effectiveness of these interventions. Evidence shows that it is easier to move up in the value chain where firms already have some knowledge in that particular technological domain, as compared to moving to newer products for which no production capabilities exist (Gehl and Roffe, 2012). For example, policy interventions to support local manufacturing of technology-intensive CSP parts and components in Morocco are not likely to be very effective, at least not at early stages of the industry's development. However, targeting policy measures to upgrade knowledge of

local firms to engage in the life cycle/value chain of solar PV and solar water heaters is more realistic, given earlier experience with these technologies.

Examples of industrial upgrading programmes abound, as they tend to be rather standardised across sectors. Box 2.12 illustrates the case of Morocco, where institutions and programmes aimed at SMEs upgrading have been established, offering not only financial but also customised individual consulting services. The case also demonstrates the importance of customising policy interventions (with respect to financing, training, management capabilities, etc.) to the needs of different type of firms existing in the sector, and for them to be aligned with the strategic orientation of the sector in order to maximise value creation.

Supplier development programmes

To further support value creation from RET, industrial upgrading programmes can be complemented by measures to encourage leading firms to engage in supplier development programmes that include training, quality standards and monitoring. These programmes are directed especially at enhancing

the technological capabilities of SMEs, enabling companies to capture value from renewable energy investments and to foster closer linkages with foreign investors (IEA-RETD, 2014, forthcoming). Such programmes help ensure that value creation opportunities are retained through the increased possibility of sourcing components and services locally.

International experience suggests that supplier development programmes are most effective when they are driven by the private sector, especially leading firms, given their capability to customise these programmes to their specific needs. The following measures have been identified to be effective for supplier development support (Altenburg, 2000; IEA-RETD, 2014, forthcoming):

» **Coordination of information on promotion measures.** To improve coordination and information flows, a special coordination unit that could develop a joint strategy might be relevant, to act as a one-stop agency for the private sector.

» **Matching between potential customers and suppliers.** Instruments to promote matching between potential customers and suppliers could include sub-contracting exchange schemes, supplier fairs and exhibitions, and information and promotion events for suppliers.

» **Economic incentives to promote supplier relations and technology transfer.** Economic incentives aimed at customers could include tax relief, subsidies and advisory services; incentives aimed at suppliers include credit guarantees, soft credit and exemption from duties.

Supplier development programmmes designed for other sectors can serve as a model for replication in the renewable energy sector. One such example is Egypt's National Suppliers Development Programme for the automotive industry, which was jointly implemented with General Motors and the Egyptian Ministry of Trade and Industry (see Box 2.13). The main lessons drawn from this programme include the need to conduct and establish: a thorough assessment of domestic capabilities among local suppliers; customized services based on gaps in the suppliers' capabilities and needs of the lead firms; and close engagement of policy makers with the private sector, both with local firms and foreign investors.

Cluster development

A cluster typically refers to "a geographic concentration of interconnected economic and innovative activities in a particular field, such as renewable energy" (IRENA, 2013a). It usually includes stakeholders from universities and research institutes, the industry and government institutions. These stakeholders have

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Box 2.12

INDUSTRIAL UPGRADING PROGRAMMES IN MOROCCO

The Agence Nationale pour la Promotion de la Petite et Moyenne Entreprise (ANPME) plays an important role in supporting industrial upgrading programmes in Morocco, offering not only financial but also individual consulting services through two initiatives, Moussanada and Imtiaz.

Moussanada offers financial support to SMEs to modernise and improve their competitiveness. ANPME provides funding for services up to 60%, limited to almost USD 74 000 per enterprise. The programme is available through three offerings: Moussanada IT, aiming to accelerate the use of information technology in SMEs; Moussanada Transverse, optimising support functions as strategy, marketing and

organisation; and Moussanada Sector, fostering the business skills of SMEs, related to the production process, procurement, design and R&D. According to ANPME, around 3 000 companies have profited from this programme so far.

Imtiaz is designed as a national investment competition for high-potential enterprises with a development project, offering tangible and intangible investment grants that correspond to 20% of the total investment. The overall objective is to increase turnover, export activities and job creation, as well as to introduce new technologies or structural changes in the specific sector.

Source: Vidican et al., 2013.

common needs for technology and infrastructure and are willing to collaborate with each other and exchange information to reach mutually beneficial outcomes. This bundling of resources, strengths and competencies has the potential to provide a unique competitive advantage (Porter, 1998). Industrial clusters are important to start up local industries and to increase competitiveness and co-operation across a range of stakeholders.

The emphasis on co-operation across a range of stakeholders is especially important during the early stage of development of a renewable energy sector. This is because addressing various risks and uncertainties of a nascent sector requires cross-sectoral actions. Leading firms are at the core of a cluster initiative as they set the framework conditions and engage SMEs through upgrading and supplier development programmes. Also, they encourage research and education institutions to work closely with the private sector on solution-oriented problems.

Evidence shows that various measures are necessary for policy makers to engage in the creation of productive clusters, including: (1) policy mechanisms that promote a mix of competition and co-operation among firms; (2) policies that emphasise linking of firms to the local/regional technological infrastructure of education and R&D institutions; partnerships across private sector, academia and government; a balanced input of resources from government and industry; (3) "nudging" private companies and inviting them to collaborate and network among themselves, trust-building and enhanced dialogue to create spillovers; (4) providing seed money and R&D to stimulate the creation of new productive firms; (5) focusing on the need to create specialised knowledge; and (6) learning and innovation based on a systems view rather than on isolated firms; and joint marketing and regional branding (IEA-RETD, 2014, forthcoming).

While cluster initiatives in the renewable energy sector are quite established in developed economies, this "classic" industrial policy instrument is still in its infancy in developing

Box 2.13

THE NATIONAL SUPPLIERS DEVELOPMENT PROGRAMME IN EGYPT

The National Supplier Development Programme (NSDP) plans to improve how local Egyptian suppliers engage with multinational companies that operate across different sectors in the country. The NSDP aims to increase the competitiveness of local suppliers through modernisation, so that they become part of the global supply chain and accredited suppliers to the international and multinational companies, such as General Motors Egypt, Mercedes, Procter and Gamble, Cadbury, Unilever, Kraft and Schneider. This Programme will lead to an increase in exports and further Egypt's economic development.

NSDP provides training, consultancy and technology transfer to help companies attain international standards. Their deployment plan provides each company with a gap analysis, details of gap closure and an impact assessment.

The NSDP takes a value chain approach to upgrading the local suppliers of the top 100 Egyptian manufacturing companies with high export potential. Each of these "mother companies" may invite 20 of their local suppliers to join the programme if they prove both serious

commitment to the programme's goal of technical upgrading and their desire to grow through exporting and contribute to the upgrading costs. In this case, the services provided are:

» Individual analysis of each supplier's technological gaps and upgrading needs to meet the standards defined by its mother company;
» Technical assistance to help the supplier close its technological gaps; and
» Consultation with the supplier about financial matters and providing credit, if needed.

In the first round, the programme provided support to 20 suppliers of General Motors. In the second round, it assisted another 220 suppliers of 30 mother companies (many of them also in the automobile sector) with technical upgrading efforts. Mercedes reported that after taking part in the programme, the average productivity of its Egyptian suppliers increased 35% and waste was reduced by 45%. One supplier confirmed that after participating in the programme, its productivity was increased by 25% and its costs decreased by 40%.

Source: The Industrial Modernisation Centre, http://www.imc-egypt.org/prgnationalsuppliers.asp (Accessed on 31 August 2013)

countries (although it has been used widely in industries outside the renewables sector). One reason for this relates to the very early stage of market development for RETs, the limited number of strong industrial players around whom cluster initiatives can be organised and limited long-term visibility with respect to market development.

In Morocco, for example, the development of an automotive sector was based on the cluster concept, with foreign companies such as Renault playing a key role in organising the cluster and engaging with other stakeholders such as local suppliers, academia and research, and training institutes. A similar attempt is being made for the emerging solar energy sector, through the efforts of the Cluster d'Electronique, Mécatronique, Mécanique du Maroc (Ce3m) (Vidican *et al.*, 2013). Given the small number of companies manufacturing specific parts and components for solar energy technologies, Ce3m's approach has been to focus on companies in complementary sectors, such as

electronics and mechatronics, and to encourage them to enter the solar energy value chain, building on their already existing cluster infrastructure (Vidican *et al.*, 2013).

Given the emerging state of clusters in developing countries, the experience of developed and emerging countries with cluster formation in the renewable energy sector can be instructive. In particular, the solar energy cluster in California (see Box 2.14, also included in IEA-RETD, 2014, forthcoming) underscores the relevance of having a strong industrial and research base (*e.g.*, in semiconductors) and opportunities that this creates for diversification into new sectors and technologies.

In addition to state or provincial governments, municipal authorities can play an important role in supporting the establishment of renewable energy industries. The city of Dezhou in China is an example (Box 2.15).

Box 2.14

CALIFORNIA'S SOLAR ENERGY CLUSTER

The development of California´s solar energy cluster benefitted from dedicated universities and research, a first-mover advantage, a strong position in the new thin film market, considerable support from related clusters, and a robust incentive plan to drive local demand and cluster innovation. Various demand-pull and supply-push policies enabled companies to locate in the cluster and to take advantage of its manufacturing and entrepreneurial resources.

Aside from market creation policies that enabled the formation of a local solar industry, a government-funded initiative, GoSolar, was set up to act as a "one-stop shop" for solar companies and consumers. GoSolar aims to increase coordination among firms performing different activities in the cluster. The agency co-ordinates governments, financing partners, contractors, new home builders and real estate professionals.

Importantly, California´s Silicon Valley and venture capital clusters have played an important role in the growth of California´s solar energy cluster. The Silicon Valley cluster continues to be the leading hub for high-tech innovation, both in the United States and worldwide. At

the same time, a synergistic interaction between Silicon Valley´s venture capital support and interest in solar technology created unique conditions for industrial development in the region.

The solar cluster has also benefitted from the California Renewable Energy Transmission Initiative, which identifies transmission projects required to meet energy goals, supports energy policy and enables permitting. Intersolar, the largest North American solar conference, held in San Francisco, has successfully created shared research and innovations across the sector.

Several factors have been identified that challenge the relative competitiveness of California's solar energy cluster. These include reduced competitiveness in PV manufacturing, fragmentation of solar technology start-ups, incentive programme stability and company relocation, and infrastructure (transmission and installation permitting). The way in which California´s authorities and other actors in the innovation ecosystem respond to these challenges, by potentially redirecting the focus of the cluster towards boosting innovation capabilities, is likely to influence the future of the solar energy sector in the United States.

Source: IEA-RETD, 2014, forthcoming, based on Gibson et al., 2011.

THE 2005 DEZHOU SOLAR CITY PLAN

Dezhou, a city of some 5.8 million inhabitants in north-western Shandong province, took on the role of incubator for the local solar industry, which had suffered from poorly developed financing mechanisms, skills shortages and a lack of quality standards. The 2005 Dezhou Solar City Plan provided incentives to business such as tax waivers, reductions, rebates, preferential land-use policies and low-interest loans. The Million Roof Project, launched in 2008, required that all new residential buildings be equipped with solar water heating facilities.

Dezhou's solar water heating use now approximately equivalent to the entire EU. A renewable energy research institute was established, and solar technology became a specialised subject taught at Dezhou Technology College and at vocational schools. By 2006, some 30 000 people were employed in solar energy-related businesses, and another 20 000 – 30% of all new jobs created in Dezhou in 2010 – were in the solar sector. The plan is to create 10 000 additional renewable energy jobs in 2011-15 (ICLEI and IRENA, 2012).

2.4.2 Value creation through the development of local capabilities

First, the value created through strengthening capacities of local firms is the knowledge that can lead to improvements of existing local products and processes. This creates value mostly in manufacturing through improvements in the quality of locally sourced products and services which 1) increase the competitiveness of the market and 2) lead to reliable installations which increases deployment. Strengthening capacities of local firms also increases the efficiency of processes which can lead to further cost reductions and hence, increased deployment. In this case, value creation is also concentrated in other segments of the value chain such as installation and O&M.

In particular, industrial clusters are important to start up local industries and to increase competitiveness and co-operation across a range of stakeholders (from the private sector, industry, universities and research institutions, and government institutions) who have common needs for technology, knowledge and infrastructure. In addition, industrial clusters can be effective in stimulating innovation in the private sector and contributing to spill-over effects in the larger economy.

The industrial upgrading and supplier development process is complex and requires continuous acquisition of new skills alongside mastery of existing procedures (Azadegan and Wagner, 2011). Such a process can enable local companies to enter partnerships with leading technology firms and to benefit from subsequent spill-over effects (Altenburg, 2000). Several factors are important for ensuring successful outcomes in

terms of value creation. They include developing and retaining skilled human resources; gaining access to financial resources; enhancing managerial capabilities and growth orientation of the entrepreneur/company; and enhancing design and engineering capabilities (Vidican *et al.*, 2013).

2.5 EDUCATION AND TRAINING

Assuming that current global trends in renewable energy deployment persist, the demand for skilled human resources is expected to continue to rise, increasing the risks of facing gaps in the skills necessary to develop the sector and create value. The adoption of renewable energy is hindered by shortages in skills in many countries today, which contributes to project delays, higher costs and instances of faulty installations (ILO, 2011). This can lead to negative perceptions about the reliability of renewables, thereby slowing their deployment and reducing the potential for overall value creation in the sector.

Education and training are the basis for economic and other value-creating activities in all fields where specific skills and knowledge are required and they are crucial to transfer knowledge and strengthen local capabilities for enabling the development of a renewable energy sector. Policies that address the requirements for the relevant skills, education and training are vital to realise the socio-economic benefits of renewable energy and maximise value creation. This section discusses the policy tools and the role of both the education and energy sectors in education and training, focusing on how they can contribute to value creation.

2.5.1 Policies to promote skills development to enable value creation

Recently, some governments have actively integrated education and training into national renewable energy support policies, and there are lessons that can be learned on how different stakeholders have contributed to bridging the skills gap. This section discusses some of the initiatives that governments can undertake, along with selected experiences in providing adequate education and training to serve the sector. A more detailed analysis on the role of other relevant stakeholders can be found in IRENA's *Renewable Energy and Jobs* report (IRENA, 2013a). The extent to which governments can intervene in the education sector depends on the autonomy of the educational institutions. When applicable, these instruments should also focus on technical/organisational support and on the regular monitoring, evaluation and design of the system, and not only on the transfer of know-how (IEA-RETD, 2014, forthcoming).

Effective and stable education and training policies are vital to support the sector and maximise value creation by ensuring the availability of the skills needed for successful deployment of renewable energy. Policy measures include strategic planning for skill needs; financing for renewable energy education, training and research; and the inclusion of renewable energy in educational programmes. Other measures that can be implemented by the education sector and the industry are discussed in (IRENA, 2013a). Education and training extends to a broad range of activities and topics, and therefore the related policies interact with other policy areas. This is why close coordination with other complementary policy areas is necessary.

Strategic planning for skill needs, education and training

Policy-making is the basis and starting point for developing a renewable energy industry and providing the relevant skills needed. Only if a comprehensive renewable energy strategy, combined with a stable and consistent policy and regulatory framework, is in place will the industry see the potential for business opportunities and value creation, and the need for adequate human resources. This skills demand triggers the education sector to provide the necessary education and training, notwithstanding a number of innovative, forward-thinking institutions and individuals that already offer related courses prior to the implementation of renewable energy policies and the establishment of an industry.

To allow adequate planning for the education sector, it is crucial to align education and training policies with the national renewable energy strategy and the respective support policies. A positive example is Malaysia's National Renewable Energy Policy and Action Plan, which demonstrates how the build-up of local expertise and skills can be included in a national renewable energy strategy in a consistent way (see Box 2.16). A well-planned strategy for education and training is key to enabling the development of a domestic renewable energy sector and creating value.

Such a strategy ideally would be based on a quantitative and qualitative assessment of the potential skills requirements and needs. The quantitative assessment, in terms of the number of jobs that would be created as a result of implementing the national renewable energy strategy, is discussed in Chapter 3. The qualitative assessment can be based on interviews or surveys to 1) analyse the skills needed for the expected occupations, and 2) identify the potential sources of skill supply offering education, training and upskilling the existing workforce, recruiting from other sectors, *etc.* (ILO, 2011). Also, there are tools that can support some of those activities, such as Capacity Development Needs Diagnostics for Renewable Energy (CaDRE) (see Box 2.17).

The identification, anticipation and provision of adequate education and training is a shared responsibility among various stakeholders, which include the public and private sector, industry associations, labour organisations and training providers. The more inclusive the dialogue between stakeholders, the higher the chances of success of a renewable energy strategy and the higher the resulting value creation.

Providing financial support for renewable energy education and training

As mentioned previously, education policies and activities should be underpinned by public support in order to create value. Public financing can support

Box 2.16

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

» Incorporating renewable energy into technical and tertiary curricula, requiring collaboration with relevant ministries and certification of training courses according to the National Skills Development Act;

» Developing training institutes and centres of excellence, meeting international quality standards for renewable energy education and promoting high-class facilities at universities; and

» Providing financial support, including technical training subsidies that are paid to individuals after they have completed renewable energy courses,

and fiscal relief for higher education that allows students to treat payable fees as deductible expenses.

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

The National Renewable Energy Plan also includes two other strategic thrusts that aim to develop knowledge and expertise: Enhancing Renewable Energy Research and Technology, which describes the need for an R&D action plan to address the need for skilled people and adequate financing; and Designing and Implementing a Renewable Energy Advocacy Programme, which consists of communication efforts with stakeholders and the general public, aiming to increase knowledge and understanding.

Source: IRENA, 2013a.

education and training in the sector and thereby facilitate value creation through various channels. These include: (1) direct financial support to education or research institutes; (2) public-private partnerships or direct measures like fellowships; and (3) grants or dedicated staff positions.

» Public bodies such as education or energy ministries can provide funding to finance renewable energy-focused research and education institutions. For example, the Masdar Institute of Science and Technology, a graduate level research and teaching university financed by the government

Box 2.17

CaDRE is a tool developed to study the existing capacity, predict future capacity needs, identify capacity gaps and provide recommendations for creating capacity development strategies. It is designed to help policy makers and capacity development/renewable energy practitioners to shape an environment conducive to the development of renewable energy.

The CaDRE handbook, which provides guidelines for planning and completing a comprehensive diagnostic of the energy landscape, is complemented by a toolbox that presents a compilation of practical tools

that facilitate the diagnostic process. For example, the provided target model for the wind and/or solar energy sector helps to identify which modifications and new developments will be needed to achieve the set targets (capacity needs), the potential of the system already in place to cope with the new challenges (existing capacities), and the functions, structures knowledge and skills that still need to be developed (capacity gaps). According to CaDRE's guiding principal, a capacity development strategy can be successful only when stakeholders are intensively engaged.

Source: CEM, 2012.

of Abu Dhabi, offers graduate-level courses in clean energy and sustainability (Masdar, n.d.). Another example is the Indian Ministry for New and Renewable Energy that provides funding for education and research projects related to renewable energy (MNRE, n.d.).

» **Public-private partnerships (PPPs) are another method to finance institutions.** The Office of Energy Efficiency and Renewable Energy (EERE, USA) supports through public-private partnerships applied research at universities in energy efficiency and renewable energy. PPPs can also provide funding for specific programmes or other vocational offerings such as dual education systems to help companies find better trained workers to hire. PPPs are also common in capacity building and education programmes that are attached to renewable energy projects, such as the Lighting Africa initiative of the World Bank and the International Finance Corporations that seeks to develop markets for clean off-grid lighting products in sub-Saharan Africa.

» **Governments can support education through direct measures** such as funding/provision of trainings, research fellowships, research equipment, professorships, other staff positions and vocational training programmes. In general, the individual and societal benefits of government spending in higher education exceed its costs (OECD, 2013).

Including renewable energy in curricula and vocational training

Governments can promote the inclusion of renewable energy topics in different streams of formal education and training, and they can work on increasing the visibility and accessibility of education and training in relevant topics. However, there is a limit to which the government can influence the education sector. Education is a field that is ideally based on consensus between various stakeholders from the public and private sector, including ministries, teachers' unions and public and private institutions. Governments play more of a moderating role rather than simply mandating actions.

Policy makers can have a relatively significant influence on the determined educational content – and have the capability to foster the inclusion of renewable energy topics – in primary and secondary education. In some countries or regions, such as Bavaria in Germany, renewable energy has become part of the standard curriculum at primary and secondary schools (mainly integrated into existing courses) (Wörner, 2010). The Sustainable Energy Authority of Ireland supports schools by providing educational material for young students. They also support energy projects in schools through awards and events.

However, policy makers have a rather limited say on the content of university studies and research areas, since these institutions are generally more independent. In such institutions, renewable energy topics can be introduced in agreements with the authorities responsible for setting the requirements for funding. In addition, such topics can be introduced based on incentives such as the receipt of special funding for renewable energy-related projects or programmes. For example, the Postgraduate Programme at the Centre for Renewable and Sustainable Energy Studies at Stellenbosch University in South Africa is funded by the South African Government's Department of Science and Technology (DST).

In institutions providing vocational education and training, renewable energy-related activities can be included in officially recognised apprenticeship regulations. In Europe, some member states are required "to ensure that certification schemes or equivalent qualification schemes become available by 31 December 2012 for installers of small-scale biomass boilers and stoves, solar photovoltaic and solar thermal systems, shallow geothermal systems and heat pumps" (EC, 2009). In this case, a top-down policy approach was used. Another example is the Microgeneration Certification Scheme in the United Kingdom that ensures that installers are certified to mount microgeneration technologies according to highest quality standards.

Governments can also engage in bilateral, regional or multinational capacity development actions, thus sharing lessons learned and supporting other countries to develop renewable energy skills and helping them create value in their own countries and industries.

This can be done through the support of regional and international agencies and institutions such as the IRENA Capacity Building Strategy (IRENA, 2012d) or the capacity building activities in the Mediterranean region (see Box 2.18).

In general, education and training efforts aim to support the entire value chain of renewable energy deployment, from project development to manufacturing to O&M, as well as all supporting processes such as policy-making, financing, etc. However, countries that have a nascent sector – such as many developing countries – and that are major importers of RETs are given the opportunity to maximise value creation through education by focusing on the segments of the value chain that are provided locally. This would avoid the so called "brain drain" in the case where educated individuals have to seek job opportunities abroad. Education and training efforts may therefore be concentrated on project development, O&M and support processes as well as building general knowledge on renewables to increase public acceptance by creating awareness of the increased business opportunities and resulting value creation. Finally, more studies should be conducted to provide well-founded data to help identify the segments of the value chain where education activities have the highest impact on value creation.

2.5.2 Value creation through education and training

The renewable energy sector is frequently faced with a shortage of adequate skills, posing a considerable barrier to deployment in both developed and developing countries. Therefore, the introduction of renewable energy topics in varying types of formal education and training is an important strategy to achieve the value creation from its deployment (ILO, 2011).

Education and training in renewables generate value in the sector by providing the skills necessary to carry out specific activities which enable the development of the industry, such as designing new PV cell materials, manufacturing a wind turbine rotor, planning a biomass plant or installing, operating and maintaining a CSP plant. There are multiple methods of acquiring the necessary skills, with varying associated efforts. They range from taking an individual course related to the topic to enrolling in a full-fledged renewable energy curriculum and conducting research on the topic. More manual and practical skills for specific professions, trades or crafts can be offered in technical vocational education and training institutions. Other methods include on-the-job training, and could occur even in the absence of renewable energy-specific education.

Box 2.18

CAPACITY DEVELOPMENT THROUGH REGIONAL PUBLIC CO-OPERATION IN THE MEDITERRANEAN REGION

In the Mediterranean region, a number partnerships have been created in recent years to promote the exchange of good practices and lessons learned on renewable energy and energy efficiency, represented through the following three examples:

» The Mediterranean Association of National Agencies of Energy Conservation (MEDENER) is promoting energy efficiency and renewable energy development in national public policies through the exchange of experiences, know-how and good practices and the development of tools adapted to the context of Southern and Eastern Mediterranean Countries.

» The Regional Centre for Renewable Energy and Energy Efficiency (RCREEE) is providing various skill and capacity development activities at a technical and non-technical level, as well as knowledge resource tools for the region.

» The development of the Euro-Mediterranean University in the city of Fez, Morocco, was announced by the Union for the Mediterranean in 2012. The first courses are expected to start in 2015, and energy engineering and solar energy have been identified as some of the priority topics to be included in the referred initial programmes. Studies in energy will encompass the three higher-education cycles (Degree, Master and PhD).

Education and training create value in the renewable energy sector only if the acquired skills are applied within the sector, which depends on the steady availability of job opportunities. Otherwise, the efforts put into specific education in the field may be unavailing, especially in the case of specific skills that cannot be applied in other sectors – such as solar or wind resource assessment. Therefore, value creation through renewable energy education and training depends on a supportive policy framework that includes deployment policies and other policies aimed at developing the industry (discussed throughout this chapter) to ensure the steady availability of opportunities in renewables. In addition, governments can implement dedicated polices aimed at developing an environment that provides the necessary skills for a thriving renewable energy industry.

2.6 RESEARCH AND INNOVATION

Research, technological development and innovation activities are becoming increasingly vital for value creation and economic growth. They are crucial for sustained development and improvement of existing technologies, and offer opportunities for enhanced adaptability, improved efficiency and reduced costs. This can lead to increased deployment of renewables, thereby positively affecting value creation. However, innovation could also have negative impacts on local value creation, such as employment, through increased labour productivity and mechanisation.

The nature of innovation itself is a "*non-linear process, springing from a mix of human ingenuity, private sector initiative, codified and tacit knowledge, networks of financial resources, intelligent management, and a measure of good timing*" (IRENA, 2013c). This means that while innovation itself can be characterised as a policy goal, it and cannot be mandated; rather, it must be enabled. This section presents the diverse policy tools that contribute to creating an environment that enables research and innovation in the sector, and then shows opportunities for value creation.

2.6.1 Policies enabling research and innovation

Governments can play an important role in cultivating innovation capacity among the broad range of stakeholders participating innovation and research

activities. In creating and sustaining such capacity, several policy tools can be considered to meet specific objectives including creating and sharing new knowledge, building competence and human capital, facilitating knowledge diffusion and developing infrastructure, *etc*. All contribute to the development of RETs and the value creation emerging from their adoption. Table 2.3 attempts to map possible policy tools and the objectives to which they can contribute.

Innovation can take place along four distinct categories: product, process, marketing and organisation. While each of these innovation categories is relevant for RETs, product and process innovation are more relevant for early-stage RETs which have not yet achieved significant commercial adoption (IRENA, 2013c). While some policies are relevant regardless of technology maturity, others are more suited to specific stages of technology maturity and development. For example, subsidies and incentives to promote new research can stimulate innovation in product and process development which is more applicable in early stages of technological maturity. As the chosen technology matures, other tools to promote innovation across all categories become more applicable such as policies that aim to build competence and human capital. An understanding of these peculiarities can support the design of targeted policies to support research and innovation and maximise value creation.

Given the diversity of stakeholders involved, research and innovation policy can benefit from being integrated into the broader national policy framework, as the latter provides a level of stability and an opportunity for multi-stakeholder engagement that might otherwise be lacking. Such an approach is reflected, for instance, in the Malaysian case, where the focus on R&D is explicit in national renewable energy policies (see Box 2.19). The example also highlights the importance of co-operation between the public and private sectors in fostering innovation in the renewables sector and contributing to value creation. The topic of design and implementation of innovation policies with regard to renewable energy technology development is further analysed in IRENA's work on *Renewable Energy Innovation Policy: Success Criteria and Strategies* (IRENA 2013c).

Table 2.3 Innovation functions and examples of policy tools

FUNCTION	EXAMPLE POLICY TOOLS
Creating and Sharing New Knowledge	Subsidies and incentives for new research, contests, and prizes, intellectual property protection and enforcement measures.
Building Competence and Human Capital	Subsidies and incentives for education and training, fellowships, scholarships, and visas for advanced degree candidates.
Knowledge Diffusion / Creating Collaborative Networks	Joining or initiating cooperating, supporting industry associations, intelectual property protection and enforcement measures that provide confidence for network participants.
Developing Infrastructure	Public-private partnerships, incentivising private development, planning for public development, and investments in public infrastructure.
Providing Finance	Loan guarantees, "green" banks, and public venture capital-style funds.
Establishing Governance and the Regulatory Enviroment	Setting standards, setting targets, taxing negative externalities, subsiding positive externalities, eco-laberling and other voluntary approches, and tradable permits.
Creating markets	Feed-in tariffs, renewable portfolio standards, goverment/public procurement, media campaigns, setting government requirements, taxing negative externalities, subsidising positive externalities, eco-labeling, and other voluntary approaches.

Source: (IRENA, 2013c)

The design of research and innovation policy should also take into consideration external factors that impact the environment for related activities in the sector. These factors include the existence of a robust market, strong linkages with research institutions, a large pool of technical capacity (scientists and engineers), among others. Table 2.4 provides a summary of the key elements and components that constitute such an environment.

2.6.2 Value creation from research and innovation

There is growing recognition globally of the potential for value creation from increased research and innovation activities in the field of renewable energy. This is demonstrated through the fact that public spending on renewable energy R&D increased from

Box 2.19

ACHIEVING VALUE CREATION BY MAINSTREAMING R&D AND INNOVATION POLICY AND FOCUSSING ON PUBLIC AND PRIVATE SECTOR CO-OPERATION: THE CASE OF MALAYSIA

In Malaysia,one focus of the National Renewable Energy Policy is to enhance R&D in the field of renewable energy. The objective is to implement a systematic R&D programme that leads to innovative products and services that can accelerate growth of the domestic renewable energy industry.

One solar energy project, MBIPV, aims to demonstrate the potential of building-integrated solar PV (BIPV) systems in Malaysia. It is a joint initiative by the Government of Malaysia and UNDP, with funding from the Global Environment Facility. The project has sought the involvement of local universities and local industry as partners to implement two research projects on BIPV. In addition,

a local testing facility for R&D activities on local manufactured products, as well as for quality control of imported PV components,has been established in consultation with international certification bodies.

The demonstration BIPV projects provided first-hand experiences for improvements in stakeholder training and skills as well as increased R&D activities. Under the project, testing facilities for mounting structures and inverters were established to improve the reliability and quality of the domestically produced technologies. Data from the monitoring of several PV installations will be used as inputs to R&D and to inform relevant policy-making.

less than USD 1 billion annually in the 1980s and 1990s, to USD 1.9 billion in 2007 and over USD 4.1 billion in 2009 and 2011 (IRENA, 2013a). As such, the correalation between research and innovation, and value creation can conceptually be established along three main dimensions.

First, the value created through promoting research and innovation is the knowledge that can lead to technological breakthroughs, improvements of products, technologies, production lines and services, and increasing the applicability of technologies to local conditions. These can reduce the cost of deployment and positively impact the deployment of renewables, thereby supporting value creation. Value is created when results from basic research are translated into commercially viable technological developments through finding technical solutions for problems, thereby achieving a higher level of competitiveness. An example of an intermediary organisation which bridges basic and applied research is the Fraunhofer Society in Germany (see Box 2.20)

Second, this knowledge can translate into a competitive edge for countries, private sector and other stakeholders operating in a dynamic renewable energy sector wherein new markets are getting unlocked (for instance, in the case of energy access) and existing ones are expanding rapidly. The other dimension is welfare wherein technology innovation can be a means to empower people and improve livelihoods.

Third, R&D efforts present opportunities for job creation as related projects generate employment for scientists and technicians at laboratories. However, the improvements resulting from innovation, along with the impact of economy-of-scale and other learning effects, could contribute to increasing mechanisation and labour productivity that eventually decreases the number of workers needed to produce a given amount of renewable energy.

2.7 CONCLUSIONS

A broad range of policies can affect value creation from deployment of large-scale solar and wind energy. It covers policies to stimulate deployment, as well as those aimed at building a domestic industry, encouraging investment and technology transfer,

TABLE 2.4 ELEMENTS OF AN ENVIRONMENT THAT SUPPORTS RESEARCH AND DEVELOPMENT

ELEMENT	COMPONENTS
Enabling environment	**Robust national and international market for "improved" products or services ensure** demand for "sophisticated" products, thus providing a continuous incentive for inventions and innovations. Additionally, feedback or interactions between the producers (technology providers) and the consumers is key to continuous improvement and innovation.
	Stable political framework that is complemented by along-term strategy, relevant policy instruments as well as an overall supportive framework conditions are key drivers for innovation.
Education and research	**Education system** that ensures professional education and training in order to transfer know-how between disciplines and sectors, and to enable people to generate new knowledge or create new products.
	Basic research centres and universities which create knowledge through fundamental research and that disseminate this knowledge through education or training in order to create a large pool of skilled labour and human resources.
	Applied research institutions which build upon the basic/fundamental research and adapt/translate it into applied science and potential commercial products.
Private sector and networks and institutions	**Company-level R&D activities** which focus on product development by integrating and adapting applied research results to their product range or production processes.
	A mix of large firms and SMEs, which can conduct their own research, incrementally improve production technologies, absorb and demand know-how from research centres and new technology based firms for high-risk investments in new products or technologies.
	Strong networks of co-operation between basic and applied research centres, universities and private sector R&D.
	Strong exchange between innovative firms and their customers to identify needs and formulate a feedback process.

THE FRAUNHOFER SOCIETY

More than 66 Fraunhofer Institutes form theFraunhofer Society, Europe's largest application-oriented research organisation, located in Germany. Each institute has a different focus on applied science fields covering topics such as health, security, communications, energy and the environment. Most of the Society's 22 000 staff members are qualified scientists and engineers, whose work balances application-oriented fundamental research and innovative development projects. The institutes offer an important source of innovative know-how for large companies as well as for SMEs that do not maintain their own R&D departments.

Energy is a main area of research, comprising 18 institutes with about 2 000 employees who focus on renewable energy (solar, biomass, wind energy), energy efficiency, buildings and components and electrical energy storage and micro-energy systems (Fraunhofer Energy Alliance, 2013).The Fraunhofer Institute for Solar Energy Systems (ISE), founded in 1981, was the first solar research institute in Europe that was not part of a university research department. It has achieved several successes in solar research (*e.g.*, high efficiency values for cells or inverters, first quintuple-junction solar cell, etc.) and currently employs about 1 300 researchers, of whom about 170 are doctoral students working in close co-operation with universities (Fraunhofer ISE, 2013). Since its foundation, several spin-offshave been established in areas including the production of concentrators and water treatment with solar energy.

Besides the close co-operation with its spin-offs and members of alliances, pooling of different skills with all Fraunhofer Institutes secures exchange and enhancement of know-how and skills and also helps to overcome shortages, gaps or bottlenecks.

strengthening capabilities, promoting education and training, and research and innovation. Identifying the relevant policy areas requires looking at the different segments of the value chain where the potential for value creation exists and identifying challenges that can hinder value creation.

Deployment policies are crucial as they trigger investment in the sector which can impact value creation with varying intensity along the different segments of the value chain, depending on the type of policy. Such policies are most successful at creating value when they enable the stable and long-term market development of renewable energy technologies while at the same time, adapting to the dynamic technological and market developments. The impact on value creation due to deployment policies also varies according to the design of the policy. For instance, the integration of local content requirements can maximise value created in manufacturing.

Local content requirements have increasingly been used by developed and developing countries with the aim to support the development of a nascent industry, create employment and/or promote technology transfer. Specific socio-economic benefits in line with national priorities can be targeted through the design of local content requirements. However, these instruments are sometimes perceived as inefficient in promoting local industrial development as they risk distorting markets by creating barriers for potential foreign market players, creating supply shortages for components and materials and resulting in increased costs and quality issues.

The effectiveness of local content requirements in creating value depends on many factors. The local content shares should not be too restrictive and the private sector should be consulted in the process of the design of the policy. The requirements need to consider existing areas of expertise and should be directed at those with the highest potential. They should also build on a sizable and stable renewable energy market, in combination with other policies that aim to facilitate financing in the industry as well as to strengthen the competitiveness of the sector in order to serve that market.

Access to finance is among the critical success factors for the development of the renewable energy sector and value creation. As such, investment-promotion mechanisms can be adopted to overcome existing financing barriers and to attract investors into the sector,

in solar and wind projects as well as in manufacturing facilities. Among other channels, these mechanisms can facilitate foreign investments in the form of official development aid that helps implement first-of-its kind projects in developing countries, or through foreign direct investments. Aside from employment creation and the development of new sectors, the latter may also contribute to technology transfer and the enhancement of domestic capabilities.

Various programmes and policies can be strategically targeted towards enhancing capabilities in the sector, such as industrial upgrading programmes, supplier development programmes and the development of industrial clusters that promote competition and co-operation across a range of stakeholders. These cross-cutting policy interventions may result not only in economic growth due to increased competitiveness, but industrial clusters also can be effective in stimulating innovation and contributing to spill-over effects.

The value created through promoting research and innovation is the knowledge that can lead to technological breakthroughs, improvements of products and services, and increasing the applicability of technologies to local conditions. These can reduce the cost of deployment and positively impact the deployment of renewables, thereby supporting value creation. Moreover, the knowledge acquired contributes to welfare wherein technology innovation can be a means to empower people and improve livelihoods. Value is created only if research activities are closely linked to the industry's challenges. The success of research and innovation policies in creating value, as for all the other policies discussed, depends on the availability of qualified human capacity.

As such, government support for education and training is vital for value creation along all the segments of the value chain and the supporting services. Education and training in renewables generate value in the sector by providing the skills necessary to carry out specific activities which enable the development of the industry. Explicit policies and measures that support skills demand are crucial for the successful deployment of renewable energy. Given the long lead times in the education sector and the rapid innovation of renewable energy technologies, immediate actions are required to ensure the availability of adequate skills.

Since renewable energy cuts across many sectors, the right policy mix to maximise value creation from solar and wind energy deployment requires close coorination and engagement of stakeholders from these various sectors. In addition, several factors are important to define the best fit policy mix and there is no one size fits all policy solution for value creation. Influencing factors include the level of development of the domestic renewable energy sector; the general business environment and competitiveness as well as the dynamics of regional and global markets for wind and solar energy components and services. These factors should be considered in defining the national long-term strategy and priorities.

In conclusion, it is worth reiterating that tremendous opportunities exist for value creation from the deployment of solar and wind energy, in the various segments of the value chain. A multitude of factors influence the choice of the right policy mix in order to maximise value creation and the success of the policy builds on realistic and credible strategic objectives, the existing industrial capacities on regional and global market developments and the country's competitiveness in these markets.

3 Measuring Socio-economic Value Creation

$$dT(t_n) = \frac{3}{(\ln 2)} \sum_{i\text{-}1}^{n} \ln\left[\frac{C(t_i)}{C(t_{i\text{-}1})}\right]$$

Chapter 1 of this report presented the variables that should be considered when assessing the socio-economic impacts of renewable energy deployment, and introduced the different segments of the value chain that they affect. Chapter 2 focused on policies for value creation, analysing the impacts of different policy areas and the right mix of policies that can maximise value. The purpose of Chapter 3 is to support decision makers in assessing the value created by different policies. This assessment would help in designing the most appropriate renewable energy strategy that takes into account key social and macroeconomic benefits, which could be compared to the cost of deployment. The chapter builds on the concepts and variables introduced in Chapter 1 (*e.g.*, the different segments of the renewable energy value chain and the possibilities for value creation in each) and introduces the different methods that can be used to assess value creation. These methods vary in scope, sophistication and data requirements, and each has strengths and limitations.

The chapter aims to help decision makers and analysts choose the most appropriate method and tool to assess the economic impacts of different policies, considering the specific questions that the assessment intends to answer, as well as the resources available for the assessment, such as time, data, and human and financial resources. Many of these aspects have been obtained through an inquiry phase directly with the developers of the tools.

The chapter starts with a discussion of both the usefulness and complexity of quantifying the economic value creation that can result from policies (Section 3.1.1). The costs of making uninformed policy decisions, without quantification of the possible impacts,

can be very high for a country. Section 3.1.2 describes the steps to be followed when choosing a specific tool and introduces some of the key modelling characteristics and classifications found in the literature. Sections 3.2.1 and 3.2.2 provide an overview of some of the methods used for assessing the economic value creation of renewable energy, focussing first on **gross** impacts and then on **net** impacts. It also provides specific examples[13], examining the four variables analysed in this report. Section 3.2.3 categorises these methods according to their characteristics discussed in earlier sections, in order to bring clarity on how the specific methods relate to the concepts discussed. Section 3.3 presents some overall conclusions.

3.1 SELECTION PROCESS

3.1.1 A complex but valuable endeavour

Quantifying the socio-economic impacts of a renewable energy strategy is a very complex process. Successful engagement requires expertise in disciplines such as policy analysis, economics (both macro and micro), mathematics and statistics. Because the quantitative assessment is typically conducted through computer-based models/tools, advanced proficiency is also needed in spreadsheet, modelling and programming languages or interfaces used for this purpose. There is also a need for sound data (which in many cases is missing), robust assumptions, as well as a high degree of expertise.

A variety of tools/models are currently available that can produce very useful insights if provided with the correct inputs. All have advantages and disadvantages, and the policy maker must understand the limitations of the analysis or modelling framework.

It is usually advisable to use several models to approach the same question, and then to compare the answers to perform targeted sensitivity/scenario analyses (see Mai *et al.*, 2013), to contrast the results with other countries/regions with similar characteristics, or to peer review the main assumptions, methods used and conclusions with other experts. Although performing such analyses can be a complex endeavour, it is usually a valuable mission: the benefits obtained in the way of informed and improved policy-making typically outweigh the costs in time, expertise or resources.

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[13] *These lists do not intend to be exhaustive. For instance, in the literature there are some well-established models such as MARKAL/TIMES, NEMS, POLES, WITCH or PRIMES which have not been included because they have significant complexity in order to address many other dimensions of the energy sector beyond the ones analysed in this report*

3.1.2 Considerations in choosing a specific tool

A potential decision-making process for the selection of an assessment tool is illustrated in Figure 3.1 which includes the following steps:

» First, policy makers must decide which variable of economic value generation (value added, GDP, welfare or employment) they are interested in assessing.

» Second, the various defining characteristics of these variables should be identified, such as sectoral and geographical scope, technological approach and mathematical technique (for example, gross, local employment calculated through top-down simulation). These characteristics are explained briefly below. Once the variables of interest and their characteristics are established, they can be matched with the outputs and characteristics of the existing tools (for example, a JEDI top-down simulation model of the local economy sector), and suitable tools

can be short-listed. These tools, their underlying methods and their outputs are summarised in greater detail in Section 3.2.

» Third, the inputs needed for the short-listed tools such as data, expertise, time and financial resources should be identified. If the inputs and requirements of the tool are feasible, the tool can then be used to assess the selected variables of economic value; otherwise, policy makers or analysts should restart at the first or second step with an adjusted requirement, changing the ambition level or characteristics of the analysed variables..

The characteristics of the variables of socio-economic value have an important role in shaping the policy-maker's overall requirements from the modelling exercise. These include sectoral and geographical scope, technological approach and mathematical technique. The relative importance assigned to each of these characteristics may vary from one policy maker to another.

FIGURE 3.1 SELECTION OF AN ASSESSMENT TOOL
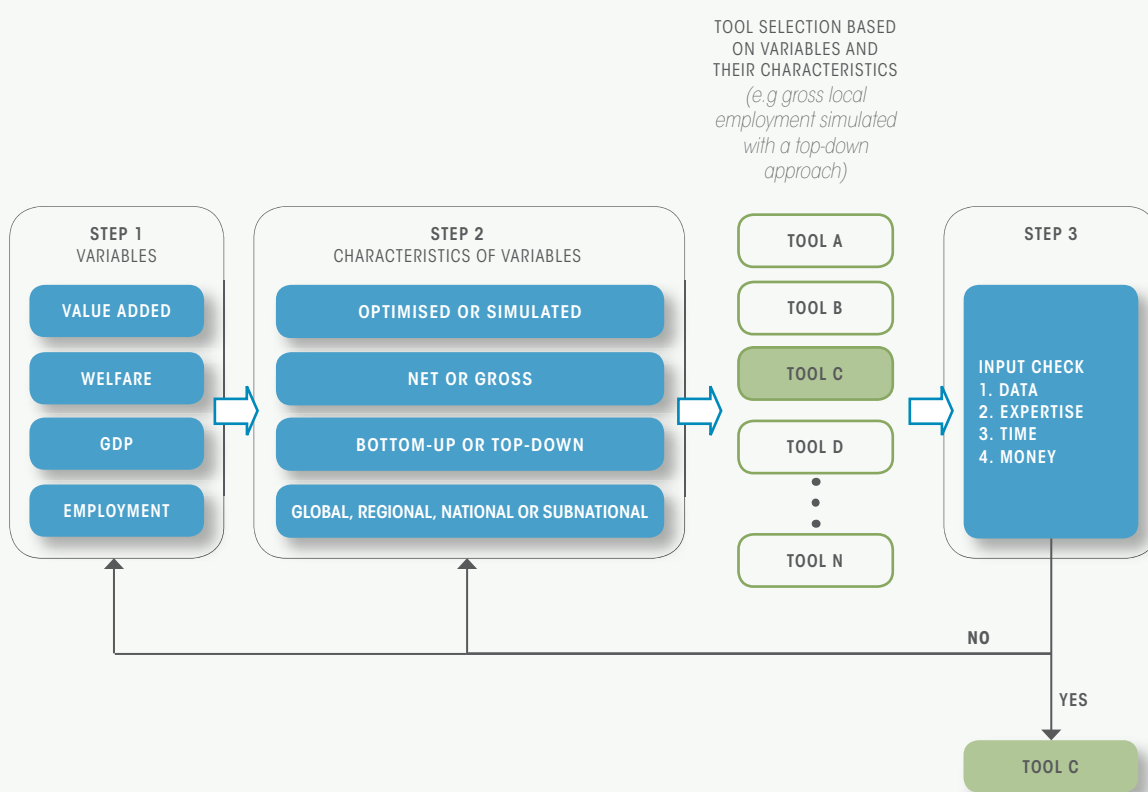
Source: IRENA

The **geographical scope** refers to a policy maker's interest in assessing economic value creation at the subnational, national, regional or global level. The **sectoral scope** refers to the coverage of economic sectors: the policy maker may be interested in assessing the economic impacts across the whole economy, usually called the "net" approach; or for only one sector (such as renewable energy, fishing, mining, etc.), usually called the "gross" approach. A gross approach is useful to gain insights in how significant one specific sector is, but it cannot be used to compare between sectors.

The **technological approach** refers to what are commonly considered "top-down" and "bottom-up" modelling approaches in the literature. Top-down approaches use large macro aggregates to derive specific figures, whereas bottom-up approaches aggregate many specific figures to produce a global total. For instance, a top-down approach would estimate the consumption of electricity in a country using population, GDP and an indicator of energy efficiency. In contrast, a "bottom-up" approach would calculate consumption as the sum of all the electric devices in the country, their level of use and their individual efficiency. This is relevant because if, for instance, a policy maker wishes to analyse the employment effects of a specific technology, a bottom-up approach may be preferable, whereas if a more macro perspective is sought, a top-down approach may be better.

The **mathematical technique** can classify assessment models within two broad families, "simulation" and "optimisation". Simulation models try to replicate reality, simulating how economic agents interact. Optimisation models, on the other hand, present the best way to accomplish a defined goal (Sterman, 1988). Policy makers must decide if they are interested in one "optimal" variable or in the "simulated" variable – for instance, if they want to see the optimal employment that a renewable energy strategy should create, or the simulated employment, which may be different.

In addition to the characteristics described above, there are others that could be considered in the selection of a tool. This includes, for instance, the degree to which a tool can depict the feedbacks between different elements of the energy sector and the economy; the representation of innovation and its linkage with

technology costs and labour productivities; or the ability of a tool to represent the complexities of human behaviour, which is related to the rate of adoption of new technologies and to the response to certain policies.

Regardless of the tool selected, analysts and policymakers should be mindful of several aspects that are essential for developing sound analysis and results. These include considerations such as scenario design, definition of system boundaries and sensitivity analyses. For further discussion of these considerations, which are not addressed in this chapter, see Mai *et al.* (2013).

3.2 OVERVIEW OF METHODS

Economic impact assessments of renewable energy deployment can be conducted using various methods that differ with respect to their applicability and data requirements. This section provides an overview of the most commonly used methods, focusing on those that are capable of addressing the key variables analysed in this report: value added, GDP, welfare and employment. The methods are classified according to their sectoral coverage ("gross" or "net").

The methods are introduced in the order shown in Figure 3.2, starting with the simplest approach on the left and advancing to methods that can deliver a more accurate picture of economic impacts of renewable energy deployment. The increase in sophistication requires better data and more detailed analysis; hence, these models tend to be more resource intensive, in terms of both human and economic resources.

3.2.1 Gross analysis: the renewable energy sector alone

Assessments of gross economic value focus on how the RET sector contributes to the total value added within an economy, without considering the possible negative effects on other economic sectors (such as the fossil fuel sector).

Critical assumptions and parameters that affect the results include imports and exports of RETs, and labour and capital productivity. Import shares of installed RET plants represent lost opportunities for local production of equipment and the associated employment (see Chapter 1).[14] If impact assessments are based on

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[14] *It should be noted, however, that even imported RET plants have positive value added in some phases of the life cycle, namely for O&M and decommissioning. See Steinberg et al. (2012) for an example of dealing with sensitivities related to assumptions on domestic production.*

Increasing scope, sophistication, data requirements, cost →

	GROSS IMPACT ASSESSMENTS		NET IMPACT ASSESSMENTS	
	EMPLOYMENT FACTORS	GROSS INPUT-OUTPUT AND SUPPLY CHAIN ANALYSIS	NET INPUT-OUTPUT	COMPREHENSIVE ECONOMIC MODELS*
Economic performance (*e.g.* GDP, value added, welfare)		X	X	X
Employment	X (only direct jobs)	X	X	X
Applicability	Quick assessments and simple monitoring of employment in the RE industry	More sophisticated monitoring of economic value creation in the RE industry	Rough economy-wide assessments for the short term	Short to long-term economy-wide assessments
Relative cost	$	$$	$$$	$$$$

Includes computable general equilibrium, macroeconometric and economic simulation.
Source: Adapted from Breitschopf et al., 2012.

renewable energy deployment investment figures and do not account for imports, they may overestimate the investment-related effects on manufacturing. Conversely, when assessments do not consider exports, they may underestimate the effects on manufacturing. Taking into account labour productivity is important because higher labour productivities require fewer jobs to generate the same level of output (Breitschopf *et al.*, 2012). Capital productivity determines the amount of economic output produced in the sector.

Three main methods are available for assessing the gross impact of the renewable energy industry: employment factors, gross input-output models and supply-chain analysis.

Employment factors

Description of the method. Employment factors are recommended for quick and simple assessments of the employment effects of the renewable energy industry. As such, they can only provide employment figures, without the possibility to assess other aspects of economic value creation. This approach can estimate employment for different segments of the RE value chain. Permanent activities, such as O&M, are described as full-time equivalents (FTE)[15] or jobs per MW of installed capacity. Temporary or one-time activities, such as manufacturing or construction, are expressed as FTE-years or person-years per MW of installed capacity.[16]

Box 3.3

DEALING WITH DATA AVAILABILITY

In countries at an early stage of renewable energy deployment, sufficient statistical data are often not available. Under such conditions, paving the way for broader impact assessments could consist of gathering primary data from industry surveys or case studies of small communities. Systematically tracking employment over time for each unit of installed RET capacity, as well as monitoring qualitative aspects of employment (such as gender, wages, skills level, job quality) can help fill data gaps (IRENA 2013). A solid input-output statistical framework, with great sectoral disaggregation of the energy industries, would also be of great help.

[15] *Full-time equivalent refers to one person working full time on a job.*

[16] *Note that it is possible to express both types of employment as "FTE-years per MW of installed capacity", by multiplying for the technical life (i.e., operation years) of the plant.*

TABLE 3.1 RANGES OF EMPLOYMENT FACTORS BY TECHNOLOGY

	MANUFACTURING & INSTALLATION (JOB-YEARS/MW)	OPERATION & MAINTENANCE (JOBS/MW)
Wind		
Minimum	2.6	0.1
Maximum	15	0.6
PV		
Minimum	7.1	0.1
Maximum	43	0.7
CSP		
Minimum	4.6	0.2
Maximum	36	1.0

Source: van der Zwaan et al. 2013

When comparing different employment factors, it is essential to consider the specific technology, country or reference period for the data and the scope of the analysis (*i.e.*, the boundaries of the renewable energy industry). Such underlying differences may help explain the wide range of employment factors reported in the literature (see Table 3.1).

Employment factor methods usually provide information on *direct* employment, *i.e.*, jobs in the renewable energy industry, and their application may be relatively inexpensive, if reliable data are available[17]. Otherwise, additional resources are required for determining the employment factors.

Data requirements. The data needed to estimate employment factors can be gathered through labour requirement analyses, technology cost analyses, enterprise surveys or expert judgement (Breitschopf *et al.*, 2012). Such data, however, are

not easily available for many countries. A practical solution is to use OECD employment factors and adapt them for different labour productivities in non-OECD countries by using a regional job multiplier, as illustrated in Table 3.2 for the construction and O&M stages of the RET supply chain in India (Rutovitz *et al.*, 2012). The regional job factor for India with respect to the OECD equals 3.6. It is calculated through the average labour productivity in India and the OECD, and it indicates that in India, labour productivity is 3.6 times lower.

Whenever possible, such adjustments should be calibrated with local data (Breitschopf *et al.*, 2012). An interesting approach for regional adjustment of employment factors is currently being used by IRENA (forthcoming), where the country adjustments of employment factors are based on labour productivities of similar industries rather than on the average labour productivity of the country.

TABLE 3.2 EXAMPLE FOR DERIVING LOCAL EMPLOYMENT FACTORS IN INDIA

EMPLOYMENT FACTORS	UNIT	PV	CSP	WIND ONSHORE
Construction (OECD)	Job-years/MW	11.0	8.9	2.5
Construction (India) (= OECD x 3.6)	Job-years/MW	39.6	32.0	9.0
Operation and maintenance (OECD)	Jobs/MW	0.3	0.5	0.2
O&M (India) (= OECD x 3.6)	Jobs/MW	1.1	1.8	0.7

Note: the regional job factor for India equals 3.6.
Source: Teske et al. 2012; Rutovitz et al. 2012

[17] *For example, the employment analysis for REmap 2030 (IRENA, 2013a) was carried out in less than one person-month.*

In addition to the regional adjustments, employment factors for a country can be adjusted across time to account for technological progress, learning effects and labour productivity improvements.

If the analysis intends to shed light on the issue of domestic production, import and export ratios in the renewable energy industry should be adequately represented. Relevant data sources for imports and exports include: trade statistics (*e.g.*, the UN Comtrade or GTAP databases), technical literature, market intelligence, expert judgement and company data (Breitschopf *et al.*, 2011, 2012; Lambert, 2012).

Case studies. Analyses based on employment factors have been conducted to determine the employment impact of RETs in various countries and regions, including the United States (Wei *et al.*, 2010) and South Africa (Rutovitz *et al.*, 2010), as well as for the world (IRENA, 2013a; Teske *et al.*, 2012). IRENA's analysis for REmap countries estimates that total employment in the renewable energy sector would grow from the current 6.5 million to around 16.7 million in 2030 if all the REmap options are implemented (IRENA, 2013a; IRENA, 2014a). A similar global analysis (Teske *et al.*, 2012) was performed using the framework of Greenpeace's *Energy [R]evolution* reports. An interesting approach is followed in van der Zwaan *et al.* (2013), where the results from a MARKAL/TIMES model for the Middle East are combined with employment factors to conclude that almost 200 000 renewable energy jobs could exist in the region in 2030.

Table 3.4 summarises existing estimation tools that have a "gross" sectoral scope. The Green Job Calculator mentioned in the table is a spreadsheet-based tool that Wei *et al.* (2010) used to estimate employment creation in the United States. The frameworks created for the other examples mentioned above (Rutovitz *et al.*, 2010; IRENA, 2013a and Teske *et al.*, 2012) also could be utilised for employment analysis.

Gross input-output

Description of the method. Gross input-output tools allow for more sophisticated monitoring of economic value creation in the renewable energy industry by providing estimates of both employment and value added as a contribution to GDP. These tools cover indirect economic value creation in upstream industries, in addition to direct. Usually, they do not cover induced effects (*i.e.*, effects from household consumption expenditures of persons employed in the RET industry and supplying industries, government expenditures, etc.) (Breitschopf *et al.*, 2012; Allan *et al.*, 2012).

The input-output method is more comprehensive than the employment factor method because it depicts the inter-industry relationships of an economy and traces how the output of one economic sector becomes the input of another (this is, in part, what will be referred to as "economic structure" in this chapter). It combines data on expenditures for renewable energy capacity expansion, replacement and operation with input-output modelling to determine the indirect economic impacts in the supplier sectors. However, this increased sophistication comes with higher resource requirements for model building from scratch, know-how, data processing, tool usage and analysis of results, which translates into an associated cost of around six person-months[18] for one study. It should be noted that most input-output methods assume that the economic structure of the country is static[19] (reflected by the input-output matrix), which limits their applicability in the case of large structural economic changes (for example, those produced by a large technological breakthrough).

Data requirements. Implementation of the input-output method requires data on renewable energy capacity and generation, technology-specific costs and cost structures (the breakdown between cost components, such as, in the case of PV technology, costs of planning, the PV module, the inverter and the rest of the system) and an input-output model supplemented by employment and other economic data. National input-output tables, published by statistical offices in most countries, represent an important data requirement for this method. This can be an important limitation for input-output analysis in most countries, which do not produce these tables with enough sectoral breakdown. In cases where national-level data are not available, adaptation of data from other countries could be considered, although this generally is not recommended because input-output tables represent the unique economic structure of a country. Employment data are sometimes published in conjunction with input-output tables, and they are normally a useful complement for the analysis. Data on

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imports and exports can be drawn from trade statistics, enterprise surveys, industry associations, the technical literature and industry experts (Breitschopf, 2011, 2012).

Case studies. The following examples illustrate the practical application of gross input-output modelling for several countries.

In **Spain,** analysis based on gross input-output modelling indicates that renewable energy overall added more than USD 9.45 billion to the country's GDP in 2009, with wind and solar technologies representing nearly 70% of this contribution. The Spanish CSP industry in particular, more than doubled its contribution to GDP as well as the number of CSP-related jobs from 2008 to 2010. Of the nearly 24 000 CSP-related jobs in 2010, more than 98% were in construction, which points to a considerable potential for local jobs (Deloitte and Protermosolar, 2011; Deloitte and IDAE, 2011; Caldés et al., 2009).

Gross economic impact analyses in the **United States** often rely on the JEDI (Jobs and Economic Development Impacts) suite of models – publicly available tools with standard input-output multipliers that can be used at the county, state, regional or national level (see Box 3.4). For example, Slattery et al. (2011) apply the JEDI Wind model to the state and local level (within a 100-mile radius around two wind farms). Another recent JEDI analysis estimates the nationwide economic impacts of renewable energy projects funded with the §1603 grant program under the American Recovery and Reinvestment Act (Steinberg et al., 2012).

Inspired by the JEDI models, the economic impact of CSP deployment was assessed for the Middle East and North Africa (**MENA)** region, with a special focus on local manufacturing potential. The analysis concludes that if the MENA region as a whole develops a strong local manufacturing industry, the total potential value added from local manufacturing of CSP plants can result in up to 79 000 permanent local jobs in manufacturing, construction and O&M (Gazzo et al., 2011).

In addition to JEDI, several other models are based on the gross input-output method. For example, ECOVALUE utilises input-output tables that are further disaggregated into renewable energy technology sectors (Martinez, et al., 2013). Table 3.4 provides a summary of salient characteristics of the JEDI and ECOVALUE models.

Supply chain analysis

Description of the method. Supply chain analysis has a more micro and business-oriented approach and is not always useful to analyse macroeconomic impacts (for instance at a national level), so it is generally used less frequently than employment factors or gross input-output. As defined by IRENA (2013), "the supply chain analysis seeks to map the specific supply hierarchy and relationships among companies in an economic sector, focusing on different levels of manufacturers and companies which provide key components and inputs".

As the name suggests, supply chain analysis helps to discern how the delivery of products and services to the end customer mobilises inputs along the supply chain, from raw materials, processing and assembly, or support services through to the final product.

Box 3.4

TOOL EXAMPLE: JEDI

Main characteristics: JEDI models are gross input-output, bottom-up, simulation tools that are freely available and estimate potential economic impacts from energy projects (renewable but also conventional power generation, or transmission lines) in terms of construction and operating expenditures that occur within a region/municipality. They are essentially gross models, but include induced effects through multipliers. The underlying data is based on actual U.S. projects and statistics, which can be a limitation in their use. However, users can customise data to represent their specific project and local economic conditions. The developer-owner of the tool is not responsible for how it is used, applied or interpreted.

Access: It requires Excel and is free to download and use. The user is responsible for their own project.

Contact: http://www.nrel.gov/analysis/jedi and jedisupport@NREL.gov

Identifying bottlenecks or hindrances to technology diffusion is a critical aspect not properly covered by the models most commonly used to analyse the entire energy sector. Hence, in-depth analyses of the production chain for a given technology are better suited for this task. A tool based on the value chain approach can help answer the following questions: "Where can employment be created? Where can the largest revenues arise? Where can there be large dependence on foreign inputs (*e.g.*, capital, materials, services or technology) along the RET supply chain?"

Data requirements. Supply chain analysis requires detailed information on companies and their interdependencies including costs, sales, intermediate inputs, imports and exports, etc. Possible sources of information include surveys and interviews with industry experts, business directories and industrial classification systems such as North American Industry Classification System or the European Community's statistical classification of economic activities (IRENA, 2013).

Case studies. Supply chain analysis has been used, for instance, to analyse the local economic impacts of renewable energy deployment in **Germany** through the WeBEE simulation tool (see Box 3.5) (Hirschl *et al.*, 2010).

Table 3.3 compares these three methods across different considerations. The different economic variables that these methods address are listed under "key variables", and then put in the context of their applicable uses. The table highlights the different levels of resources needed for each method, as well as the different assumptions at the heart of each method.

This section presented several examples of tools for gross assessment of variables of economic impacts. Table 3.4 summarises key information about these and other tools that have a gross sectoral scope. The list does not intend to be exhaustive; it provides a few examples of the many tools available. The table highlights the tools' inputs, outputs (the questions they can help answer) and characteristics. These tools have been selected based on the following attributes:

» They are used by policy makers, governments and international organisations, and their capabilities are widely recognised.

» They are used to solve questions similar to the ones that are addressed in this report.

» The developers were responsive to our enquiry and to the prospect of working with new-user countries, which could imply modifications and enhancements to their existing databases and/or functionality.

Box 3.5

TOOL EXAMPLE: WEBEE

Main characteristics: WeBEE is a supply-chain analysis simulation tool that focusses on the components and services necessary to produce, install and operate a renewable energy technology. Value chains are represented in four segments in which value added can be created: the Systems Manufacture and Planning & Installation stages reflect one-time impacts, whilst the Operation & Maintenance (O&M) and System Operation stages include annually recurring effects. Two main value-added components are calculated, which yield a local value-added impact: profits of the participating companies, and net incomes of the employees involved. The tool also calculates municipal taxes paid on business profits and on adjusted gross employee income; hence, it allows one to understand the distribution of the created value added among households, firms and local government.

Access: The tool is run by the developer-owner, hosted by the German Renewable Energies Agency (www.unendlich-viel-energie.de/), and analyses can be performed through fully specified projects or via individual queries. A simplified online version can be accessed and used free of charge.

Contact: Bernd.Hirschl@ioew.de and http://www.ioew.de/en/under-the-ioews-spotlight/value-added-and-employment/. Much of the available information is in German, which may be limiting.

TABLE 3.3 COMPARISON OF GROSS METHODS

GROSS APPROACH	EMPLOYMENT FACTORS	GROSS INPUT-OUTPUT MODELS	SUPPLY CHAIN ANALYSIS
Key variables	» Employment only » Only direct jobs in the RE industry	» Employment and other economic impacts (value added) » Covers indirect jobs in upstream industries	» Micro/business perspective » Direct and indirect employment and value creation in upstream value chain
Applicability	» Quick assessments and simple monitoring of employment in the RE industry	» Medium to high, depending on data quality	» Quantification of economic value creation at a project or company level
Resources needed	» Low (if employment factors are easily available) to high (if they have to be derived)	» Medium	» High (significant detail needed on companies within the value chain and their relations)
Critical assumptions/ data requirements	» Imports (domestic production), exports, labour productivity, labour input by RET » Need to disaggregate data per RE technology	» Imports (domestic production), exports, labour productivity, labour input by RET » Static input-output tables assume no change in economic structure	» Imports (domestic production), exports, labour productivity, labour input by RET » If results want to be extrapolated to national level, assumptions about equal value chains

Source: Based on Breitschopf et al. 2011, 2012; Allan et al. 2012; Cardenete et al 2012

3.2.2 Net analysis: the whole economy

Net impact assessments analyse whether renewable energy deployment has positive or negative effects on the economy as a whole. These economy-wide effects can be measured as changes in GDP, welfare or total employment relative to a hypothetical reference scenario[20] with a lower share of renewable energy deployment, as illustrated in Figure 3.3. Critical assumptions and data requirements include those mentioned in the section on gross studies (imports, exports and labour productivity), as well as the development of economic and demographic growth, energy efficiency, fossil fuel prices, renewable energy generation costs and CO_2 prices[21] Constructing reference scenarios generally makes net assessments more resource intensive than gross assessments (Breitschopf *et al.*, 2011; 2012, Mai, 2013).

Four main methods are available for net impact assessments: net input-output, computable general equilibrium models, macroeconometric models and simulation models. Net input-output is limited in scope, because the input-output tables used for this analysis only consider the productive sectors in an economy while excluding the demand sectors, the government or international trade.

In contrast, the three other methods can be considered comprehensive models that reflect the behaviour of all market participants. Due to this expanded scope, they are more costly to use and may require about three person-years[22] for building and applying the model.

Such models are often run by universities or national research institutes, so the choice of modelling approach may be constrained by the availability of domestic models and experts. Their applicability range from a time horizon of a few years (short term) to several decades (long term). All four approaches are based on input-output tables or social accounting matrices (SAM, similar to an input-output matrix but also considering demand sectors, international trade, or government) as the underlying database of economic structure and interactions (Breitschopf *et al.*, 2012).

Net input-output

Description of the method. Net input-output modelling represents the relation between all producing sectors in the economy – that is, how goods and services flow between them. It does not include international trade, government or demand sectors and is similar to the gross input-output approach in this regard. The main difference is that net input-output

Tool	QUESTION, INPUT AND OUTPUT		CHARACTERISTICS			
	Questions Related to econValue/Outputs of the Model	Inputs Needed	Sectoral scope	Technological approach	Geographical scope	Mathematical technique
Green Jobs Calculator	» Employment per sector	» Direct employment factors and indirect jobs multipliers » Percentage of renewable energy sources in the energy mix	Gross	Bottom-up	National (United States)	Simulation
ECOVALUE	» GDP » Economic activity levels per sector » Employment and wages per sector, including skill, age, gender, rural or urban and job-quality considerations » Emission reductions » Fiscal impacts in different taxes and at municipal level	» Input-output (I-O) tables » Data for RE disaggregation in I-O tables (RE usage data) » Energy mix » Emissions inventory » Geographic (sub-national) location of RE deployment » Data on employment per sector (skill, age, gender and job quality) from national employment statistics	Gross input-output (with RETs disaggregated in I-O table)	Top-down	National, but includes sub-national detail	Simulation
JEDI	» Local/municipal impacts of RE deployment (can also be used for conventional technologies, such as gas- or coal-fired, and even for transmission lines) » Direct, indirect employment and economic impacts (induced jobs are estimated through multipliers) » Tax generation	» Renewable energy deployment (e.g., MW) » Input-output matrix for the municipality/state » Economic multipliers for employment, wages and personal spending » Development and equipment costs » Details on local supply chain » Portion of equipment and services produced locally » Local tax rates » Ownership and financing structures (for advanced users)	Gross input-output (also includes multipliers for induced effects)	Top-down	Local (municipal or state level in the United States)	Simulation
WeBEE	» Clear focus on local (municipal) effects of renewable energy deployment » Company profits (after tax) » Net Income of employees » Municipal taxes paid (corporate and income taxes) » Local employment effects » Activity levels (production) in companies in different segments of the supply chain	» Detailed information on the value chains for renewable energy technology » Structure of the supply chain (e.g., A supplies to B, B supplies to C and D, D imports fom X country, etc.) » Details on all suppliers in different levels of the supply chain (e.g. companies, costs, employers, revenues, etc.)	Supply chain analysis	Bottom-up	Local (municipal)	Simulation
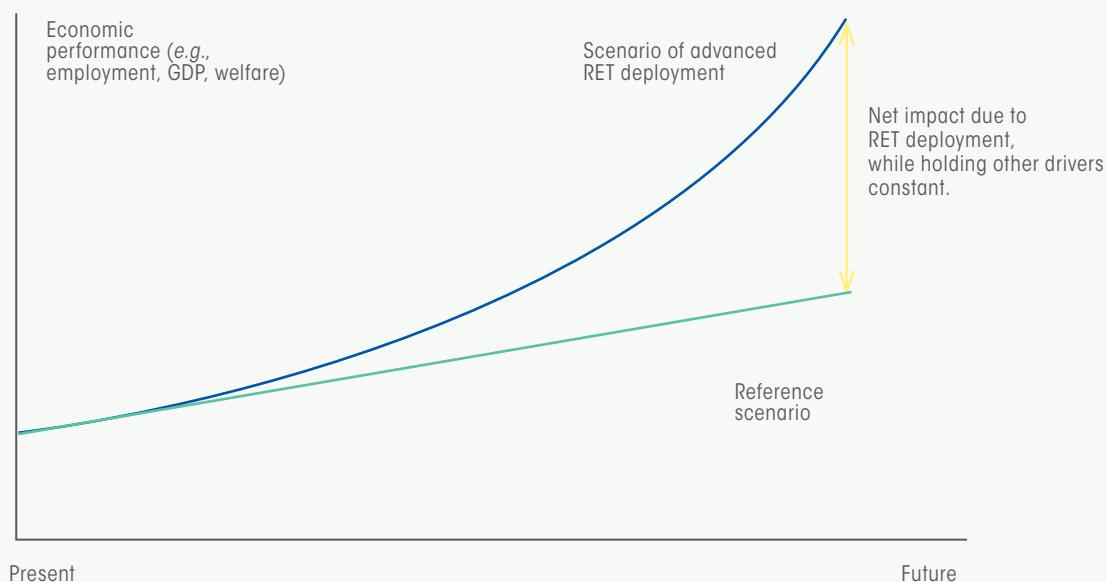
Note: the net effect in this figure is positive for illustrative purposes, but it could also be negative, i.e. the yellow arrow that refers to the difference could be below the reference scenario.

modelling compares two different scenarios – one with advanced RET deployment and one without – to yield a net effect. Some authors disagree, stating that net input-output is not a true net analysis since it fails to capture all feedbacks across the entire economy.

This method is limited in its ability to capture structural economic changes and dynamics because it is based on input-output tables, which usually represent a static picture of the economy. The model does not include interactions between prices and quantities, capital accumulation processes[22] or changes in consumer preferences and technologies. This approach has the advantage of being less resource intensive than the other net modelling options presented in this section.

Data requirements. The data needed include those for gross input-output modelling, as well as several other statistics regarding induced effects (for example, prices in other markets in the economy, including for power and CO_2[23]) and for constructing a reference scenario (Breitschopf *et al.*, 2012).

Case study. In Greece**,** the net impact of RET deployment and energy efficiency measures was calculated from 2010 to 2020 using a net input-output modelling approach. The analysis found an overall net increase in output and employment, which is reduced correspondingly if substantial components for solar PV and wind installations need to be imported (Markaki *et al.*, 2013).

Computable general equilibrium models

Description of the method. Computable general equilibrium (CGE) models complement the net input-output models to represent the entire economy, including households, government, international trade, investment and all the interactions between them. Households supply labour and capital to producing sectors, where these inputs get transformed into goods and services for consumption by households. This flow of inputs and outputs is depicted as a set of demand and supply equations that correspond to microeconomic consumption and production theories.

Generally, these models adopt the strict assumptions (normally associated with neoclassical economics) that all economic agents are perfectly rational and have perfect information, households maximise their utility and companies maximise their profits, and all markets are in equilibrium. It should be noted that these neoclassical assumptions are as strong as assuming full employment or perfect competition in all markets. Using these assumptions, a set of equations can be obtained. CGE models solve such systems of equations to an equilibrium at which supply and demand are balanced across all markets for goods and services. The prices of these markets are also revealed during this process (Breitschopf *et al.*, 2012; Allan *et al.*, 2012, Mai, 2013).

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[22] *In economics, capital accumulation refers to how an investment is used to purchase physical equipment (e.g., factories, infrastructure) which will normally improve economic output.*

[23] *The same comment on CO_2 prices as stated before applies here*

Given their strict neoclassical assumptions of optimising agents, perfect information and efficient markets, CGE models are well suited for long-term impact assessments that give economic actors enough time to adjust, assuming there are no large structural changes in the economy. Furthermore, some types of CGE models are well-suited to illustrate the un-anticipated long-term effects of a given policy. Additional strengths include their foundation in microeconomic theory, which offers great flexibility in evaluating a range of different policy impacts to the economic system within a consistent framework, and their ability to assess policies at the regional level, even when regional time-series data are not sufficiently available (Breitschopf *et al.*, 2012; Allan *et al.*, 2012).

CGE models have several weaknesses. First, it could be argued whether their neoclassical assumptions hold in reality (it is widely acknowledged that economic agents such as households and firms are not fully rational and do not have perfect information, and that markets do not always reach equilibrium situations). Second, they cannot represent large structural economic changes (*i.e.*, they are normally based on static SAM matrixes[24]). Third, there are no formal diagnostic tests for evaluating the appropriateness of the equations used to represent households' and firms' behaviours. In addition, other data apart from the SAM matrixes are often used in CGE models (such as substitution elasticities relevant for representing trade flows or how households prefer some goods over others), which may have limited information available for their estimation. According to some experts, these issues make CGE analysis especially challenging or even incorrect in the context of developing countries, where the assumption of equilibrium can be weaker, although this may also be the case in industrialised countries.

Data requirements. Development and use of CGE tools requires significant data inputs and modelling expertise, making these models highly resource intensive. To some extent, parameters needed can be derived from (static) input-output tables. Yet CGE models need further data sources to characterise the economy more comprehensively in the SAM, which also represents households, the government, etc. This requires data about national accounts, government accounts, balance of payments and trade (Allan *et al.*, 2012; Caldés *et al.*, 2012).

Case studies. Nonetheless, CGE models have been used in many countries to assess the potential for value creation due to renewable energy. A recent CGE

analysis for Germany assessed the overall employment and welfare impacts of different ways of financing the subsidies for renewable electricity generation. Results from the model show that doing so through a labour tax tends to yield negative effects, while financing generation through a levy on consumed electricity has positive effects if the levy is not too high (Böhringer *et al.*, 2013).

Two earlier CGE analyses for the European Union (EU-15) assess the impact of support policies for RET that aim to reach 30% renewable energy-based electricity by 2020. Both studies find negative effects on two measures of economic performance: welfare (-0.08%) and GDP (-0.8%) (Dannenberg *et al.*, 2008). However, technology costs have decreased significantly since these studies were conducted, possibly affecting these conclusions.

For South Korea, a CGE assessment shows the impact of renewable energy policy and related public expenditure from 2008 to 2010. For the short term of three years, the growth rate of GDP increases by 0.16% and about 14 500 jobs are created. Over ten years, the growth rate of GDP will increase by 0.58% and about 51 000 jobs will be created (KEIS, 2012).

Macroeconometric models

Description of the method. Sectorally disaggregated macroeconometric models, based mainly on advanced statistical techniques, are best suited for prospective, short- to medium-term economic impact assessments. Unlike the CGE models, macroeconometric models do not make the strict neoclassical assumptions of full information, perfect rationality of economic agents (citizens, firms, etc.) and substitutability of all factors (labour, capital, resources, etc.). Instead, these models assume historical observed relations (which may represent imperfect, but realistic, behaviour of economic agents and market imperfections) to remain true for the future. For this reason, macroeconometric models may be more correct in their predictions for the short-to-medium term (when one can assume that past relations are still true), whereas CGE models may be more correct for longer-term analysis (when the neoclassical assumptions could be relatively more correct compared to past relations).

Macroeconometric models have several strengths, the most important being their ability to represent the imperfections of the economy (*e.g.*, imperfect information, unemployment, imperfect rationality) that contradict the neoclassical assumptions. This is because they

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[24]   *Dynamic CGE models also exist, in which this may not be the case.*

assume that the statistical relations that described the past will hold for the future, and within them, the existing market imperfections. But this can also be one of their main weaknesses, as past relations do not always remain true for the future. For example, a change in the economy due to a major technological innovation may make econometric extrapolation of previous economic conditions less applicable. Another weakness is that these models may not adequately reflect the microeconomic structure of the economy. When compared to CGE models, macroeconometric models tend to assess benefits of RET support policies slightly less pessimistically (Breitschopf *et al.*, 2012; Allan *et al.*, 2012).

Data requirements. Using a macroeconometric model requires long time-series data for parameter estimation and model specification, as well as significant knowledge of advanced statistical techniques, which leads to higher resource intensity and costs. While such time series are, at least in OECD countries, often available for key macroeconomic and sectoral indicators, they may be more difficult to obtain for other countries or for disaggregated, RET-specific applications. Many macroeconometric models rely on data, relations or even structures from the system of national accounts (such as input-output tables and SAM matrixes). However, if the method is based on macroeconometric relations, this report classifies them as macroeconometric models (instead of input-output models, for instance).

Case studies. In **Poland,** a specific macroeconometric approach – a dynamic stochastic general equilibrium (DSGE) model – was used to assess modernisation and the transformation to a low-emission economy, including renewable energy production. This multi-sector model represents the Polish economy with two-way dependence between decisions of individual entities and the state of the economy as a whole for a time horizon to 2050. The results show that, in the first decade, a low-emission economic transformation scenario affects GDP and employment negatively relative to a reference scenario. Subsequently, however, the low-emission transition will affect the economy in a positive way, increasing GDP by more than 1% and employment by 0.1% by 2050 (Bukowski *et al.*, 2013).

Another study used a macroeconometric model to project employment effects in **Germany** to 2030. Using different assumptions for fossil fuel prices, international trade and domestic installations, the analysis concludes that

RET deployment has a positive net impact on employment for almost all the scenarios and years analysed, and rises as scenarios with greater levels of German exports lead to more positive impact increases (Lehr *et al.*, 2012b).

Given that CGE models and macroeconometric models are built on fundamentally different assumptions about the economy (perfect markets and rationality vs. replication in the future of past relations which represent realistic, imperfect behaviours), it is useful to apply both to a single policy analysis and to compare results from each method. This was done recently in **Europe** when analysing the proposed 2030 climate and energy policy framework, where the GEM-E3 general equilibrium model and the E3MG macroeconometric model were both used (European Commission, 2014).

Another interesting study using the E3ME macroeconometric model (see Box 3.6) was recently published analysing the economic impacts of wind energy development in **Ireland,** concluding that such development would contribute to economic growth (Pöyry Management Consulting and Cambridge Econometrics, 2014).

Economic simulation models

Description of the method. Economic simulation models are suitable for long-term assessments, although they are used less frequently to assess economic impacts of RET deployment than the other approaches discussed here. They are not built on any specific underlying theory or economic paradigm. On the contrary, they are a pure representation of the relations between variables that are believed to occur in reality. They allow for more nuanced interactions than those found in the two preceding approaches. Due to their complex structures, they also come with high cost. Their mixed character – with attributes of both econometric models and equilibrium approaches and different theoretical economic foundations – can be seen as a strength, but also as a weakness (Breitschopf *et al.*, 2012). Another weakness may be their reliance on parameters which can be hard to estimate, understand and explain – factors that tend to reduce model transparency and trustworthiness.

Case study. In one study, the net impact of RET deployment on GDP and employment was modelled using a system dynamics model (a type of simulation model) for the **EU-27** with a time horizon of 2030. The results demonstrate that GDP increases continuously

TOOL EXAMPLE: E3ME

Main characteristics: E3ME is an econometric, net, top-down (with bottom-up elements in the power sector) simulation tool whose structure is based on the system of national accounts. It includes the main components of GDP (consumption, investment and international trade). Equations are disaggregated by country and by sector. National energy and environmental policies (*e.g.*, support to renewables) are some of the main inputs, and the model calculates how the economy responds to them.

Access: Details of applicable fees per project are available upon request from the provider. E3ME

is usually run by the developer but can also be made available under licence. Typical projects are organised around scenario analysis on behalf of clients.

Relevance: This tool has been used to answer questions about outputs in projects such as "Impact Assessments of Energy Taxation Directive and Energy Efficiency Directives" and "Green jobs study for European Commission (2011)".

Contact: www.e3me.com and hp@camecon.com

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in all scenarios to 2030, relative to a baseline without renewable energy support policies in place. The relative change in employment is also positive but follows more diverse patterns (Ragwitz *et al.*, 2009).

Table 3.5 compares the four net analysis methods discussed in this section. It highlights the key attributes of the methods and puts them in the context of their applicable uses, ranging from short- to long-term assessments. The table describes the different level of resources needed for each method, as well as the different assumptions made.

This section has described some examples of net economic analysis tools (*e.g.*, E3ME). Table 3.6 highlights additional tools beyond those mentioned and details their inputs, outputs and characteristics, with their selection based on the same criterion as described above.

3.2.2 Categorisation of methods by characteristics

Tables 3.4 and 3.6 highlighted some of the salient characteristics of specific tools (*e.g.*, JEDI, E3ME). However, a comprehensive discussion of the characteristics of each method (gross input-output, macroeconometric, etc.) is still lacking. This section categorises the specific methods presented in Sections 3.2.1 and 3.2.2 by some of the model characteristics presented in Section 3.1.2. Table 3.7. organises the existing methods introduced for assessing socio-economic impacts of renewable energy by three of their characteristics (sectoral scope, mathematical technique and technological approach).

It should be reiterated that this categorisation is not claimed to be definitive. Exceptions may always exist; for example, simulation models can be used in conjunction

TABLE 3.5 COMPARISON OF NET METHODS

NET APPROACH	NET INPUT-OUTPUT MODELLING	COMPREHENSIVE ECONOMIC MODELS (ALL ECONOMIC SECTORS)		
		MACRO-ECONOMETRIC	COMPUTABLE GENERAL EQUILIBRIUM (CGE)	ECONOMIC SIMULATION
Key attributes	Medium data requirements; very limited dynamics	Assumed relations require time-series data for parameterisation	Assumptions of optimising agents and perfect markets	Complex structures with many feedback loops
Applicability	Rough net assessment for the short term	Short- to medium-term assessments	Long-term assessments	Long-term assessments
Resources needed	Medium to high	Very high	Very high	Very high
Critical assumptions/ data requirements	» Imports (and hence domestic production), exports, labour productivity, labour input by RET » Development of economic and demographic growth, energy efficiency, fossil fuel prices, RET generation costs and CO_2 prices			

Source: Based on Breitschopf et al., 2011, 2012; Allan et al., 2012; Cardenete et al., 2012.

	QUESTION, INPUT AND OUTPUT		CHARACTERISTICS			
Tool	Questions Related to econValue/ Outputs of the Model	Inputs Needed	Sectoral scope	Technological approach	Geographical scope	Mathematical technique
AMIGA	» Production and employment per sector » Income and GDP effects » Energy mixes » Distributional effects (it includes household disaggregation) » Investment needs in energy infrastructure » Government spending » Trade balance » R&D issues » Emissions	» For the United States, a very detailed SAM matrix » For the other world regions, SAM matrixes data from GTAP database » Economic elasticities » Population and productivity forecasts » Bottom-up data for energy production and demand sectors (costs, efficiencies, capacities, etc.)	Net, large detail in United States (200 sectors), less detail in other regions	Top-down combined with bottom-up for energy supply and demand sectors	National (U.S.) with great detail, combined with a less detailed global representation	Simulation combined with optimisation
ASTRA	» GDP » Investment in the energy and transport sector » Employment in the energy and transport sector » Trade balance » Income	» Main exogenous drivers, e.g. population » Labour productivity » Energy prices » Emission factors » Consumption split » Technological costs	Net (greater detail in transport and energy sectors)	Mixed bottom-up and top-down	National (Germany, Italy) Regional (Europe) Global	Simulation
EPPA	» Output per sector and per region » GDP per region » Consumption per region » Employment per region » Welfare per region » Emissions per region (greenhouse gases and others) » Fossil fuel depletion and prices » Trade balances » Land use (adequate for bioenergy analyses) » Capital stock accumulation	» SAM matrixes, per region, from GTAP database » Population and productivity projections per region » Energy efficiency levels per region » Elasticities of substitution for households and firms » Trade elasticities » Fossil fuel resources per region » Emissions intensities	» Net (global CGE model, greater detail on energy and agriculture sectors) » 9 non-energy sectors » 15 energy sub-sectors	Top-down (bottom-up detail in energy sector being developed)	Global, in 16 regions	Optimisation
E3ME	» Output per sector and per country, including prices and gross value added » GDP and its components per country » Household consumption per country and income level (i.e., distributional effects of policies) » Employment; labour supply, wages and unemployment per sector and country » Emissions per sector and country (greenhouse gases and others) » Trade balances » Energy demand per sector and fuel, and energy prices	» Population » Data on national accounts » Energy and environmental policies » Prices of fossil fuels (e.g., world oil price) » Rest of world economic activity and prices for the represented goods » Inputs on power market (technological costs, power prices, etc.)	Net (macroeconometric model with 69 sectors)	Top-down with bottom-up detail of power sector	» Regional European, 33 countries » There is a similar model with global coverage: E3MG	Simulation (macroeconometric)
PANTA RHEI	» GDP » Investment in energy sector » Trade balance » Employment » Income	» System of National Accounts (input-output tables) » Environmental accounts and emissions inventories » Energy balances	Net (macroeco-nometric, based on I-O structure)	Bottom-up	» National (prepared for Germany)	Simulation

with optimisation algorithms to arrive at optimal solutions. Even if not perfect, Table 3.7 is included here in an attempt to bring further clarity to the discussion.

Methods that are classified as gross are employment factors, supply chain analysis and gross input-output methods. All three have a simulation rationale, since they represent what will happen for the given data (in the form of capacities, costs, employment per unit of capacity or observed economic relations between production sectors), without addressing if the output is optimal. However, both the employment factors and supply chain analysis approaches could be considered to be "bottom-up" because their main data are detailed technical and economic quantities (*i.e.*, the capacities in the different technologies, supply-chain characteristics). In contrast, the gross input-output approach can be considered to be "top-down" since it uses macroeconomic aggregates (such as the input-output table) to calculate the effects in the renewable energy sector and upstream industries.

Net input-output models are top-down and based on simulation, for the same reasons as gross input-output, but they are net as they consider the complete economy. CGE models are also top-down (they are built on macroeconomic data in the form of the SAM matrix) and net. They have an optimisation rationale since the economy is assumed to reach an ideal situation where all markets are in equilibrium, all households have maximum utility and all firms have maximum profits.

Macro-econometric models are also net and top-down, but they have a simulating rationale as they assume that past conditions hold in the future, without assessing if this outcome is best. Finally, economic simulation models are also net and have a simulation rationale. They can be both bottom-up (if the represented relations have a largely technical perspective and the macro figures are based on an aggregation of them) or top-down (if the represented relations are directly between macro figures).

3.3 CONCLUSIONS

The importance of assessing the socio-economic impacts of renewable energy deployment is being increasingly recognised in international debates. Sound information on expected impacts, such as employment and income generation, is essential to enable informed policy choices. It also helps in monitoring policy effectiveness and in communicating the benefits of these policies to the wider public with reliable facts and figures. In the past, however, policies have been implemented without clearly understanding their full economic effects, which can be a significant risk for their medium-term economic sustainability and associated policy stability. This is why the exercise of quantifying the economic impacts that are expected from those policies is crucial. However, it is a complex process that could be resource intensive.

Conducting such an assessment requires solid data on the renewable energy sector that: i- complies with international reporting standards in order to ensure comparability among countries; ii- is collected over

TABLE 3.7 METHODS CATEGORISED BY THEIR MODEL CHARACTERISTICS

		SECTORAL SCOPE			
		GROSS (ONLY ONE SECTOR)		NET (ECONOMY)	
		MATHEMATICAL TECHNIQUE		MATHEMATICAL TECHNIQUE	
		OPTIMISATION	SIMULATION	OPTIMISATION	SIMULATION
Technological approach	Bottom-up	Employment Factors			Economic simulation (*e.g.* System Dynamics)
			Supply Chain Analysis		
	Top-down	Gross Input-Output			Net input-output
				Computable General Equilibrium	
					Economic simulation (*e.g.* System Dynamics)
					Macroeconometric

long time series; and iii- reflects a clear definition of what each data category does and does not include (for example, if a new sector is created in national statistics for solar PV, the data definitions need to be very clear about how this sector is defined and where its boundaries are). However, data gathering is challenging, as such information is not normally captured in standard national statistics due to the cross-cutting, sometimes highly decentralised and relatively new nature of the renewable energy sector. In addition, not all countries are able to bear the costs associated with data collection and may lack the institutional capacities to handle the data. Countries with insufficient data can start their data collection efforts by adding specific questions on the renewable energy sector to existing statistical surveys, by gathering primary data from industry surveys or by developing case studies, the results of which can then inform a country-wide data collection strategy.

The process of quantifying the socio-economic impacts of renewable energy deployment can be time-consuming and in some cases does not fit easily with the time frames of the policy-making process. The first step in this process is defining the question to be answered, which includes choosing both the variables to be assessed (employment, GDP, etc.) and their characteristics (gross or net; regional, national or sub-national; obtained by optimisation or by simulation, etc.). The second step is to select the most appropriate tool for the assessment, where outputs and characteristics need to match the exact question to be answered. The third step is to assess if the inputs required for the chosen tools are available, both in terms of resources (expertise, time and money) and in terms of data and solid information to make the needed assumptions. Finally, if the required inputs can be secured, engagement with the tool can be initiated (downloading it from the web, contacting the developers, attending training sessions, etc.). Otherwise, the level of ambition of the study would have to be reduced.

Depending on the question and tool selected, gathering the data and running the model could take between a few months up to a couple of years. If solid data are systematically collected, and the human expertise is established and maintained (for example through a

statistics, modelling and policy analysis department), the developed tools could be used for many years for different policy assessments, bringing a prolonged benefit via better informed policy-making. Indeed, a key requirement for successfully engaging in such a process is the human resources and expertise needed in disciplines such as statistics, economics, policy analysis, modelling and advanced computer literacy, including programming. These skills are not always readily available, and this task could be outsourced, but over the long term it may be more sustainable to establish in-house capabilities.

Numerous tools are available, with different underlying methods (employment factors, gross input-output, CGE, macroeconometrics, etc.), data and resource requirements (some of the tools are freely available online), degrees of sophistication, levels of applicability, etc. Their underlying methods, which range from simple employment estimates to comprehensive economic models, can be differentiated into gross and net impact assessments.

Gross impact assessments focus exclusively on one sector (for example, the wind energy sector) and as such are relatively simpler and less resource-intensive approaches. They include employment factors, gross input-output and supply chain analysis. Net impact assessments represent the whole economy (all sectors) and as such can provide a broader picture of the economic impacts of renewable energy deployment (for example, if the overall impact is positive or negative); however, they also have larger data and resource requirements. They include net input-output models, CGE models, macroeconometric models and economic simulation models.

Finally, it should be noted that no approach fits all needs perfectly, and that the results of a modelling exercise should not be interpreted as a precise forecast of what will happen. The results depend strongly on the quality of the data, the assumptions and the underlying modelling method. Comparing results obtained from different models, performing targeted sensitivity/scenario analyses, analysing results obtained for other countries/regions with similar characteristics and peer reviewing conclusions with other experts, is usually advisable.

4 Key Recommendations

The findings of this report indicate that in designing and implementing policies to maximise value creation, policy-makers may consider:

Analysing socio-economic value creation of renewable energy

» Assessing the impact of solar and wind energy deployment on value creation is critical for making informed policy decisions. Value creation can be measured by macroeconomic variables such as value added, gross domestic product, welfare and employment. Given the cross-sectoral nature of the renewable energy industry, the analysis should be conducted along the different segments of the value chain.

» Policy makers should pursue value creation depending on local conditions and the stage of renewable energy deployment. In each segment of the value chain of wind and solar energy projects (including project planning, manufacturing, installation, grid connection, operation and maintenance and decommissioning) value is created by different industries in the delivery of the respective sub-products and sub-processes. Countries at early stages of development have higher potential for value creation in activities such as operation and maintenance, or grid connection. With further developments, many opportunities for domestic value creation arise in other segments of the value chain.

Adopting the right policy mix to maximise value creation

» Policies that stimulate deployment and aim at building a domestic industry by encouraging investment and technology transfer, strengthening capabilities, promoting education and training, as well as research and innovation greatly affect value creation. It is, therefore, important that policy makers develop an appropriate mix of policies tailored to country conditions and priorities.

» Close coordination and engagement of stakeholders from different sectors is key for the success of both policy-making and policy implementation. Policies should be designed as part of a holistic framework that is consistent with and supports a well-defined national strategy. In addition, a predictable long-term policy framework for renewable energy market development is necessary to ensure stability in the value generated through deployment.

» Policy choices aimed at developing a domestic industry need to be tailored to countries' particular strengths and weaknesses. For instance, the design of local content requirements should consider existing areas of expertise along the different segments of the value chain and be directed at those with the highest development potential. Such policies should be accompanied by measures to enhance firm-level capabilities, develop relevant skills, and advance research and development.

» In enhancing firm-level capabilities to increase the level of competitiveness of domestic firms, policy makers may consider measures such as industrial upgrading programmes, supplier development programmes, and cluster development.

» In developing the relevant skills, policy-making should include the identification, anticipation and provision of adequate education and training in the sector. Including renewable energy subjects in existing and new educational programmes should be encouraged, and financial support to relevant institutions should be provided. Cooperation and cohesive action between the private and public sectors, industry associations and international organisations can help ensure the success of such policies.

» Policy makers may consider promoting research and development activities that can help address challenges faced by local industries and facilitate spin-off products to maximise value creation. To create an enabling environment for research and innovation, supporting measures can include funding, building competence and human capital, facilitating knowledge diffusion and developing infrastructure.

Gathering data and estimating value creation

» Many tools can be used to estimate the socio-economic impacts of solar and wind energy deployment, with different scope and capabilities. The most appropriate tool should be selected based on the specific socio-economic impact to be quantified and on human and financial resources available.

» Governments need to systematically collect data required for a rigorous estimation of the value creation impacts of renewable energy deployment. Data availability can be improved by adding targeted questions to industry and statistical surveys, or by developing case studies. The data should be well defined and collected over a long time series, as well as comply with international reporting standards to ensure comparability among countries.

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