Asia-Pacific
Economic Cooperation

Advancing Free Trade
for Asia-Pacific Prosperity

Sector Study on Environmental Services: Renewable Energy

APEC Policy Support Unit
October 2017

Prepared by:
Tilak K. Doshi
Managing Director
Doshi Consulting, Singapore

Asia-Pacific Economic Cooperation Policy Support Unit
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 6891-9600 Fax: (65) 6891-9690
Email: psugroup@apec.org Website: www.apec.org

Produced for:
Asia-Pacific Economic Cooperation
Committee on Trade and Investment

APEC#217-SE-01.28

TABLE OF CONTENTS

1. INTRODUCTION 1
2. COVERAGE AND DEFINITIONS 2
3. RENEWABLE ENERGY SECTOR CHARACTERISTICS 10
3.1 SMALL HYDROPOWER 18
3.2 ONSHORE AND OFFSHORE WIND 19
3.3 SOLAR PHOTOVOLTAICS (PV) 20
4. BUSINESS MODELS IN THE RE SECTOR 21
4.1 STAKEHOLDERS AND CONTRACTS IN THE RE SECTOR 22
4.2 UTILITY BUSINESS MODEL FOR RE INSTALLATIONS 23
4.3 OTHER BUSINESS MODELS (LEASING, DEALER CREDIT AND ESCOs) 25
Relating Business Models to Trade in RES 26
5. BARRIERS TO TRADE IN RES 30
5.1 ISSUES TO CONSIDER IN OVERCOMING BARRIERS TO TRADE IN EGS 32
6. CONCLUSION 34
GLOSSARY 36
BIBLIOGRAPHY 37

LIST OF TABLES

Table 1: US GATS Offer in Energy-related Services, 2003……………………………… 3
Table 2: List of Services Accompanying Environmental Goods………………………… 6
Table 3: Global Trends in Renewable Energy Investment by Technology ($ billion)…………………… ……………………………………………… 12
Table 4: Global Trends in Renewable Energy by Major Economies/Regions ($ billion)... 13
Table 5: Investments in RE in Top Ten Economies in 2016………………………………14
Table 6: Medium Term Outlook on RE Capacity Growth by Major Regions/ Economies (GW)………………………………………………………………….18
Table 7: Stakeholders and Contractual Relations in RE Projects………………………….22
Table 8: Restrictions on RES Trade and Business Models………………………………..28

LIST OF FIGURES

Figure 1: Global Weighted Average LCOEs for New Grid-connected Project…………. 15
Figure 2: Recent Announced Long-term Contract Prices for Renewable Power by Date of Announcement……………………………………………………..……… 17
Figure 3: Utility Business Model for a Power Company………………………………….24

1. INTRODUCTION

As pointed out in the "Background Note on Environmental Services" by the WTO Secretariat, there is no accepted common definition to the term "environmental services".[1] There is no simple way to make a distinction between a narrowly defined set of environmental services (such as sewerage treatment, waste collection treatment and disposal, sanitation and remediation services) and a wider set that serve to protect the environment in its broadest sense. The latter would include assistance in reducing air pollution and achieving the aspirations of the Paris Agreement on climate change.

The Terms of Reference (TOR) in the *APEC Sector Studies on Environmental Services* Request for Proposals (RFP) document states the objective of this paper as follows: "to build and enhance understanding of the wider range of services in environmental industries/businesses among APEC economies with a view to identifying key challenges". By "wider range", the RFP document refers to environmental services "beyond those listed in CPC94".[2] In this proposal, we refer to environmental services in the renewable energy (RE) business. This research project proposal seeks to build and enhance our understanding of environmental services in the RE sector, specifically in the power generation sector which uses technologies associated with solar photovoltaics, wind turbines, and hydroelectricity. This would include services in project development and project financing.

This paper is organized as follows. Section 1 provides a brief discussion of coverage and competing definitions of renewable energy and renewable energy services and the conventions followed by the UN and WTO classification systems. Section 2 gives an overview of key market characteristics and trends of the renewable energy sector, including investments, market size, and installed renewable energy capacities. Section 3 covers a discussion of business models in the solar photovoltaics, wind-power and small hydropower sectors. In section 4, the focus is on barriers to trade in renewable energy services with a view to understanding some of the constraints on negotiators in working towards liberalization of trade in renewable energy services. In the conclusion, we provide summary remarks on policy priorities that may be considered in defining renewable energy services with a broader view on the different services that are critical inputs to the optimal deployment of renewable energy technologies both in the large existing markets as well as the emerging and nascent markets.

---

[1] WTO, August 2010, "Background Note on Environmental Services: Note by the Secretariat" accessed at https://docs.wto.org/dol2fe/Pages/FE_Search/FE_S_S006.aspx?Query=(%20@Symbol=%20s/c/w/*%20)%20and%20(%20@Title=%20background%20note%20)%20and%20(%20@DocumentDate%20%3E=%202009/01/01%2000:00:00%20)&Language=ENGLISH&Context=FomerScriptedSearch&languageUIChanged=true#

[2] APEC Policy Support Unit, Survey of Regulatory Measures in Environmental Services, http://publications.apec.org/publication-detail.php?pub_id=1769 ; "CPC94" refers to "Sewage and waste collection, treatment and disposal and other environmental protection services", see United Nations, 2015, "Central Product Classification (CPC) Version 2.1", accessed at https://unstats.un.org/unsd/cr/downloads/CPCv2.1_complete%28PDF%29_English.pdf

2. COVERAGE AND DEFINITIONS

Renewable energy services (RES) are typically defined as the range of services associated with the generation, transmission, distribution and sale of electricity and heat from renewable energy (RE) sources which include wind, solar, biomass, biofuels, geothermal and tidal/ocean.[3] The coverage of renewable energy resources usually excludes the large hydro-electricity sector.[4] This study covers wind, solar and "small hydro" sectors (defined as smaller than 50MW). RES includes all services related to the planning, design, construction, operation and maintenance of RE installations. The front-end of RE projects focus on planning, design and engineering services. Project financial and management services as well as operations and maintenance (O&M) occurs throughout the duration of the RE project in operation.

The RES category as defined above is not separately listed in standard classification lists used by multilateral agencies. RES largely fall within 3 broader "UN Central Product Classification" groups: services incidental to energy distribution; other professional, technical and business services; and construction services. Economies that have signed the General Agreement on Trade in Services (GATS) use the Services Sectoral Classification List (W/120) drawn up by the World Trade Organization (WTO) to help organize and define the scope of specific commitments they have made in their national schedules[5] economies. However, as already mentioned, RES do not appear separately on this list.

WTO members typically use a "checklist" approach to schedule GATS commitments.[6] Under this approach, members create a list of services identified in the W/120 that they consider relevant to the sector in question and that they agree to the scope of that sector for scheduling purposes. The RES category as defined for this study (all services associated with the generation and distribution of electric power utilizing wind, solar PV and "small" hydro resources) would fall under the following "W/120" categories: scientific and technical consulting, services required for electricity distribution, professional services, construction and engineering services, management consultancy and financial control, and equipment maintenance and repair. For example, in the checklist of energy-related services included in the U.S. GATS offer in 2003,[7] the following CPC codes were identified:

[3] For instance, see International Energy Agency (IEA), undated, "Topics: Renewables", accessed at https://www.iea.org/topics/renewables/

[4] Hydroelectricity accounted for 71% of total renewable energy output in 2015 (IEA MTMR 2016); the "large hydro" sector (defined as more than 50MW) is expected to show slow growth as environmental and social dislocation costs pose hurdles to large projects in most economies. "Small hydro" which accounts for less than 5% of total hydro capacity is typically included in the RE sector.

[5]The Central Product Classification (CPC) constitutes a complete product classification standard covering all goods and services. The UN-adopted system serves as an international standard for assembling and tabulating product detail, including statistics on industrial production, domestic and foreign commodity trade, international trade in services, balance of payments, consumption and price statistics and other data used within the UN system of national accounts. United Nations, Department of Economic and Social Affairs
Statistics Division, Statistical Papers Series M No. 77, Ver.2.1, "Central Product Classification (CPC) Version 2.1" accessed at https://unstats.un.org/unsd/ cr/downloads/CPCv2.1_complete%28PDF%29_English.pdf

[6] United States International Trade Commission (USITC), "Renewable Energy and Related Services: Recent Developments", USITC Publication 4421, August 2013.

[7] WTO, 2003, "Council for Trade in Services—Special Session—Communication from the United States—Initial Offer," TN/S/O/USA, September 4, 2003, cited in USITC, "Renewable Energy and Related Services: Recent Developments", 2013, p. 1-3.

Table 1: US GATS Offer in Energy-related Services, 2003

CPC Code Version 1.1	Description
5115, 883	Services incidental to mining
8675	Certain related scientific and technical consulting services 887 Services incidental to energy distribution
861, 862, 863, 8672, 8673, 9312, 93191, 932	Certain professional services, including engineering and integrated engineering services
6111, 6113, 6121, 621, 622, 631, 632	Distribution services, including commission agents, wholesale trade, and retail trade services that apply to fuels, related products, and brokerage of electricity
633, 8861-8866	Maintenance and repair of equipment, except transport-related equipment
865	Management consulting and related services
511-518	Construction and related engineering services
7131	Pipeline transportation of fuels
7422	Storage and warehouse services, particularly bulk storage services of liquids and gases
8676	Technical testing and analysis services

Source: WTO, "Council for Trade in Services—Special Session—Communication from the United States—Initial Offer," TN/S/O/USA, September 4, 2003

While Paragraph 31 (iii) of the Doha mandate calls for the reduction or elimination of trade both tariffs and non-tariff barriers on environmental goods and services (EGS), the lack of an accepted definition of just what tariff lines constitute EGS in full or predominantly have led to protracted and unsuccessful negotiations over the scope of goods and services that could be taken up for trade liberalization. Freer trade in environmental goods and services (EGS) would reduce the costs of mitigating pollution at the local, regional and global levels to the benefit of all economies participating in international trade. However, most of the liberalization efforts to date have focused on barriers to trade in environmental goods only, with less attention paid to environmental services.

Investments in RE technologies such as solar PV, wind power and small hydropower show a strong complementarity between environmental goods (such as solar panels, wind and water turbines and "balance of systems" components such as cabling/wiring, fuses, batteries, controllers, inverters, switches, disconnects, meters, etc.) and the services required to install and use such equipment. Numerous services are essential to the proper delivery, installation and operation of RE equipment. Environmental goods and services are inextricably linked. This strongly suggests that efforts to liberalise trade in RES and the current negotiations to address obstacles to trade in environmental goods cannot be considered independently. In this context, the APEC agreement on the List of Environmental Goods is instructive (See Text Box 1 below).

Box 1: APEC Trade in Environmental Goods

In September 2012, Asia-Pacific Economic Cooperation (APEC) Economic Leaders endorsed the APEC List of Environmental Goods. The List had been developed "to reduce by the end of 2015 applied tariffs to 5 percent or less, taking into account members' economic circumstances, without prejudice to APEC economies' positions in the World Trade Organization (WTO)". In January 2016, the 21 APEC economies published details on the implementation of tariff cuts on a list of 54 environmental goods with the aim of achieving a number of benefits including reduced air and water-pollution, improved energy and resource-efficiency and facilitation of solid waste disposal. Trade liberalization in the EGS sector can also be effective for economic development and employment, and enable the transfer of skills and technology. Most generally, trade liberalization in EGS can help in achieving sustainable development goals laid out in global mandates such as the UN Millennium Development Goals and the UNFCCC environmental aspirations.

The APEC List contains 54 6-digit sub-headings of the Harmonized System (HS). In most cases, however, any particular item in the EGS sector is only part of the 6-digit "tariff-line" item. The 6-digit tariff lines are typically too general to exclusively or even predominantly capture the trade in EGS. Lower tariffs often apply only for certain environmental goods or services or 'ex-outs.' "Ex-outs" is a term used to indicate that only part of the particular 6-digit tariff line is included as EGS. Only these ex-outs would then benefit from lower tariffs. Thus, it is difficult to identify precisely what portion of imports come under particular 6-digit sub-headings correspond to any particular EGS item. Only in some cases does the HS sub-heading refers exactly to a particular environment good or service. For example, the item HS 850231 refers to wind-powered electricity generation sets which are clearly an EGS item. HS 854140 (photosensitive semiconductor devices) can be termed a predominantly EGS item even though it includes light emitting diodes (LEDs) as well as solar photovoltaic (PV) devices (the latter being an EGS item). Of the 54 agreed items, 15 are related to renewable energy, while the other items are related to "Environmental Monitoring, Analysis and Assessment Equipment", "Environmental-protection" (principally air pollution control (APC); management of solid and hazardous waste (SHW) and water treatment and waste-water management (WWM) and Environmentally Preferable Products (bamboo)

The issue of definition of EGS is further complicated by the fact that some goods can used for both environmental and non-environmental purposes. The APEC declaration signed in 2012 to voluntarily liberalize tariffs on 54 EGS tariff lines, however, is significant as it is the first time a large and important group of trading partners have decided to liberalize trade for an agreed list of environmental goods. While the APEC agreement led to no attempt to adopt a consistent definition of EGS, the adoption of 54 broad product categories for tariff reduction to 5% or less by the APEC economies has been a significant move forward, even if these are not legally binding and voluntarily implemented. It is still too early to judge how substantial the eventual tariff reductions may be. Much will depend on how individual APEC economies implement their commitments to free trade in EGS and how they will define the relevant ex-outs for which they would decide to reduce applied tariffs in their own tariff schedules.

The sales of RE technologies depend on a substantial component of associated services. According to the WTO, "the role of services as input into manufacturing production often termed 'servicification' of manufacturing, is substantial with services value added accounting for almost a third of manufacturing exports in developed economies and 26% in developing economies."[8] Trade in environmental goods such as the RE technologies examined in this paper is part of this trend. Typically, several services are sold together with RE technology as a package and the customer is unable to properly use the RE technology without the associated services that are embedded in the product. These accompanying services are thus indispensable for trade in RE technologies to take place. A study by Sweden's National Board of Trade found that a number of services were indispensable for the trade in environmental goods, and proposed the joint liberalisation of trade in environmental goods and associated services given their "synergetic relationship".[9] The U.S. International Trade Commission concluded similarly in the case of the US solar, wind, small hydropower, and geothermal sub-sectors, concluding that "a broad group of services are indispensable to the development and functioning of renewable energy projects."[10]

While the evidence is clear that complementarities exist between traded goods and services, this phenomenon is likely to be particularly important in the case of EGS given that the latter often lie at the top of the "complexity ladder".[11] The installation and operation of RE equipment in the solar PV, wind and hydropower sectors can be complex. Users need specific knowledge and skills that are costly to acquire. The need for such knowledge or intellectual property and skills is critical in the successful deployment of RE technologies. It is important to note that consumers of RE-generated power do not value solar panels, wind turbines or water turbines as such. Rather, they need to deploy RE technologies in combination with associated services such as installation, technical support, training, and maintenance of equipment. Therefore, policy-induced barriers on such services also discourage the deployment of RE technologies.

While there are many lists of RES compiled by various agencies working on trade-related matters, a simplified scheme is reproduced below in Table 2. The type of services listed in the table is based on the United Nations Provisional Central Product Classification ("W/120") used in GATS. However, the services are not as strictly defined by the specific CPC codes but described with the aim of reflecting the relevant services as appropriately as possible. While this list is not an exhaustive one, it provides a reasonable guide to the kinds of services that accompany deployment of RE technologies covered in this paper.

---

[8] Lanz, Rainerand Maurer, Andreas, 2015, "Services and Global Value Chains: Some Evidence of Manufacturing and Services Networks", *WTO Working Paper* ERSD-2015-03.

[9] National Board of Trade, 2014, "Making Green Trade Happen – Environmental Goods and Indispensable Services", Stockholm.

[10] United States International Trade Commission (USITC), 2013, "Renewable Energy and Related Services: Recent Developments", USITC Publication 4421 August 2013.

[11] Sauvage, Jehan and Timiliotis, Christina, 2017, "Trade in Services Related to the Environment", OECD Trade and Environment Working Papers 2017/02.

Table 2: List of Services Accompanying Environmental Goods

Type of Service	Purpose of Service	Mode (GATS)
Assembly and installation including construction	RE technology deployment	1,2,3,4
Technical testing and analysis	RE technology deployment	1,2,3,4
Educational & Professional Services	Assure proper deployment, improve user efficiency	2,3,4
Advisory and Consulting and Financial Control	Fulfil customer demand, satisfy regulations, adopt appropriate business model including financing	1,3,4
Maintenance and Repair (O&M)	Assure proper deployment, improve user efficiency	1,3,4
Computing and Software	RE technology deployment	1,4
Research and Development (R&D)	Customization to local conditions and user needs	1, 3, 4

Source: Adapted from US International Trade Commission, 2013, "Renewable Energy and Related Services: Recent Developments", Investigation No. 332-534, August.

In the last column, the typical modes of services supply as defined by the GATS are shown. Cross-border supply (mode 1) covers services flows from the territory of one economy into the territory of another economy. Examples of Mode 1 would include data or algorithms provided from a consulting office in the host economy to clients overseas via the Internet or remote, cross-border monitoring services to manage wind farms. Consumption abroad (mode 2) refers to situations where a service consumer moves into another economy's territory to obtain a service. Engineers travelling overseas to receive training in energy performance contracting from a service provider in another economy would be a pertinent example for Mode 2. Commercial presence (mode 3) implies that a service supplier of one economy establishes a territorial presence, including through ownership or lease of premises, in another economy's territory to provide a service. Presence of natural persons (mode 4) consists of persons of one economy entering the territory of another economy to supply a service. This mode includes self-employed persons and employees on temporary assignment (intra-corporate transferees).

RE technologies associated with solar PV, wind power and small hydropower involve assembly and installation skills and knowledge. Due to the complexity of the technologies (especially for wind and small hydropower), specialised skills and special equipment are often required for assembly and installation. Mode 3 and 4 are the predominant modes of supply as the assembly and installation work often requires a physical presence at the customer's site, although host economies can establish vocational courses that teach the necessary skills and have accreditation standards for local staff for some technologies such as solar PV assembly and installation. According to the CPC system, assembly and installation services are classified differently as a function of which product they are related to. According to the explanatory notes for the CPC Version 2.1,[12] the most appropriate category of services related to the EGS on the APEC list is "services incidental to the manufacture of metal products, machinery and equipment" (CPC 885), as this category is related to industrial goods. Some services would

[12] World Trade Organization (WTO), 2010, "Background Note on Environmental Services – Note by the Secretariat". Council for Trade in Services, S/C/W/320.

come under the category of "architectural, engineering and other technical services" (CPC 867) or "installation work" (CPC 516) under the "construction work" division. Assembly and installation services related to software are part of "computer related services".

Technical testing and analysis services (TTA) applicable to the RE technology concerned are provided in order to assure the basic functioning of the technology. Depending on costs, these services can be either done at the technology provider's economy or at the customer's economy. These services can be provided via service modes 2, 3 and 4. Under CPC V 2.1 definitions, TTA services are generally covered under category 8676. In some cases, however, these services might also come under CPC 94 "environmental services". TTA services related to software de-bugging or up-grades come under the "computer related services" category (CPC 84).

Technical support and educational services are a function of the complexity of the RE technology concerned. The more complex the RE technology, the more critical will be the customers' dependence on the relevant technical services. Such services are almost always critical to trade in the RE technologies. These services are often supplied as an educational program with a work plan that would include intensive "learning by doing" training. Companies supplying the RE technology typically offer training about maintenance and basic repairs with the aim of teaching the customer (which could be a local company that undertakes RE deployment projects for its end-customers) how to perform such services by themselves as necessary. Such training course can take between a few days to a few weeks at the customer's location (mode 3 or 4 delivery) or at the manufacturing company's facility (mode 2) when necessary. These services do not easily match CPC codes: they may be covered under "adult education" (924) and "other education" (929) categories. However, as these are practical courses, they might be more relevantly captured under the category "integrated engineering services for turnkey projects" (code 8673).

Advisory and consultative services associated with RE technologies can range widely. For instance, an ESCO for solar PV-derived power supply would need to provide design and architectural support to install solar PV panels into homes or buildings to achieve optimal results and maximum yield efficiency. These services come under the categories "advisory and pre-design architectural services" (code 86711) and "advisory and consultative engineering services" (86721) which include services concerning environmental issues (e.g. studies of the environmental impact of an activity). These services play an important role in the deployment of larger-scale solar farms, wind-farms and small hydropower projects, all of which have significant impacts on the local environment. These services are delivered in an early phase of a project, as part of the permitting process and site preparation, and the modes of service supply are 3 and 4 since they require presence at the location where the RE technology is deployed.

Maintenance and repair ("O&M") services accompany all deployment of RE technologies, and come into effect after the sale and installation of the equipment. These services are associated with the warranty of the product. Typically there is a "free service" period for a limited duration, with the customer free to extend the service package at a competitive price thereafter. For complex products such as wind or hydro turbines and their "balance of systems" components where product brands are important measures of quality, the customer may not have the option of choosing competing companies that offer O&M services. For instance, a customer purchasing GE turbines for wind or hydropower projects will be "locked in" with respect to their choice of services companies that can perform O&M services to either GE itself or in some cases to a list of companies certified by GE for performing such services on its manufactured products. This applies less to the solar PV sub-sector, as solar panels and their balance of systems components are far more “commodified”. The skills and knowhow needed for providing O&M service requirements in small scale applications (as in households) are relatively less demanding, and often smaller local companies are in a position to deliver such services.

For the more technologically complex RE systems (such as wind and small hydro), customers typically continue to buy the services from the original equipment manufacturer (OEM) for the duration of the RE system’s operating life. O&M including repairing services, as well as the supply and installation of spare parts, are usually a substantial part of the OEM’s revenue stream. It is also common for customers to be trained to perform O&M services for themselves after a defined warranty period as part of the technical training package offered by the OEM. Many OEMs outsource such service offerings to local distributors or joint venture partners, or they have established foreign subsidiaries (mode 3). Some OEMs, especially in the more technically complex RE sectors send their staff across borders when “on-demand” repair work is needed (mode 4). In the CPC system, maintenance and repair services for industrial goods are located in the category “agricultural, mining and manufacturing services” (CPC 88). Repair services for machinery and equipment come under CPC 8862.

In the RE sector, computer-related services are a central feature. Software is an essential part of the operation of RE technologies, although it is less important in small-scale solar PV applications. Software is also essential for services delivered over the internet (such as technical testing and technical information and diagnostics), as many of the RE systems have computer systems as an integral part of their operations. For instance, wind turbines have integrated software that monitor and control the performance and measures performance degradation. Computers are programmed to adapt the wind turbine to the current wind velocity.[13] It is important to note, however, that computers and associated software are ubiquitous throughout the global value chain of most manufacturing products, and do not only apply to the case of complex technical products involved in the RE sector. The delivery of computer services is done through mode 1 over the Internet. However, mode 4 might be necessary during all three stages – installation, operations and maintenance. Almost all services related to software come under CPC 84.

Different domestic regulations and standards as well as different local geographical and climatic conditions, the deployment of RE technologies often need a high level of customization. R&D services form part of this customising requirement. R&D is also related to the work done to improve and customize products specific to the needs of a customer. Although most corporate R&D work is already integrated into the manufacture and design of an RE technology, and hence this is not delivered as an internationally traded service to a customer. But, R&D is indispensable to the process of customization of any RE technology deployment. To acquire the specific knowledge about local regulations, natural environment and the customer’s specific needs, providers of RE technologies have to send their R&D staff overseas (mode 4). Data transfer and remote technical diagnostics may also be needed (mode

[13] PC Control, 2008, “PC Control for wind turbines”, PC Control Special Edition, February 2008 issue accessed at http://www.beckhoff.com/english/pdf/applicat/pcc_0208_Special_PC_Control_for_wind_turbines_e.pdf

1). R&D services come under CPC 85. Services which require software come under "computer related services" (code 842).

3. RENEWABLE ENERGY SECTOR CHARACTERISTICS

Currently, we live in a "fossil-fuel civilization", as Vaclav Smil terms it.[14] In 2015, approximately 85% of commercial primary energy (CPE) was supplied by the trio of fossil fuels: coal, oil and natural gas.[15] About 8% is contributed by nuclear and hydro-electricity. The carbon intensity of commercial primary energy remains high and there is little evidence of an accelerating energy transition at a global scale despite the rapid growth rates of the "newer" RE technologies such as solar and wind energy. Despite relatively rapid growth (from a small base) over the past 25 years, solar and wind-based energy account for about 1.3% of commercial primary energy. If modern biofuels (such as bio-diesel and corn-based ethanol) are included, then this goes up to 2.5% of CPE.

Given the small existing contributions of these newer technologies and their very low capacity utilization factors, rapid growth rates in RE capacity (currently growing at about 6-7% compared to overall growth of about 1.5% for CPE growth) make relatively small contributions to the overall distribution of global fuel sources of primary energy expended. It is also important to note that the current growth rates of newer RE technologies are not extraordinary by historical standards: coal and oil use grew as rapidly in their hey-day: while coal grew at around 5% per annum (pa) during 1850-70, oil at 8% pa during 1880-90, and natural gas at 6% pa during 1920-40.[16]

Most long run forecasts still see fossil fuels providing over 70% of world CPE in 2040.[17] Most widely-cited forecasts project the new RE technologies and biofuels providing no more than 15% of total global CPE by 2040. Displacing fossil fuels in the power generation sector is less difficult than displacing oil and gas in transport and petrochemical feedstock use. There is an extensive literature on the high costs of displacing liquids use in transport by substituting ethanol for gasoline and diesel or by electrification. Displacing coal use in power generation in the non-OECD economies remains the primary challenge to gaining momentum in de-carbonizing economies on a global scale.

Despite the relatively limited role that the RE sector is expected to play in global energy use, the sector has gained critical importance in terms of policy priorities over the past two decades or so. Public policies over the last few decades have supported the expansion of renewable-energy-based electric power sources to reduce pollution and the emissions of greenhouse gases through the avoidance of electricity produced from combusting fossil fuels. This is due not only to widespread concerns of the impact of local and regional air pollution, especially in the large urban areas of the developing economies, as well as, in the longer term, the prospects of adverse global climate change due to greenhouse gas emissions. The imperatives of economic growth and employment have also led policy-makers in many of the larger economies to promote technology innovation and domestic manufacturing capability in the RE sector. This

[14] Vaclav Smil, 2016, "Examining energy transitions: a dozen insights based on performance", Energy Research and Social Science, 22 (2016), 194-197.
[15] The data in this paragraph is based on BP, "Annual Statistical Review of World Energy 2016".
[16] V. Smil, "Energy Transitions", ibid, p. 195.
[17] See for instance, energy forecasts by BP, ExxonMobil, International Energy Agency (IEA) and the US Energy Information Administration accessible at their web-sites.

section covers key developments in the supply, demand, technology and cost trends of RE with a focus on solar PV, wind energy and small hydro power.

In 2015, the RE sector as defined by the International Energy Agency (IEA)[18] accounted for 23% of global power output, of which hydropower accounted for 71%, wind for 15%, and solar for 4%. Given the predominant role of large hydropower, we adopt the definition of RE that excludes large hydropower. As can be seen in the Table 3 below, solar, wind and small hydro power account for over 70% of total investments in RE. Given that RE capacity expansion is expected to be fastest in solar PV and wind power, the share accounted for by the three sources has increased over the past decade to over 90%. Over the period 2004 –2016, global investments in the RE sector (which excludes nuclear and large hydro power) increased by an annual compound growth rate of 15%. While investments in wind power increased by 16% annually, investments in solar power (predominantly utilizing PV technologies) grew by 21%. Small hydro, as can be seen, accounts for a very small share of total investments in RE technologies (amounting to less than 1.5% of total investments in 2016). Wind and solar accounted for about 47% each in total investments in RE in 2016, dominating total investments in the sector.

[18] In IEA's definition, RE includes of bioenergy, hydropower (including pumped storage), onshore and offshore wind, solar PV, solar CSP, geothermal, and ocean technologies.

Table 3. Global Trends in Renewable Energy Investment by Technology Type ($ billion)

														CAGR %	
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2004-16	2015-16
total	47.0	72.7	112.7	159.3	781.4	178.3	243.6	281.2	255.5	234.4	278.2	312.2	241.6	15%	-29%
wind	19.6	28.5	39.7	61.1	74.8	79.7	101.6	84.2	84.4	89.0	106.5	124.2	112.5	16%	-10%
solar	11.2	15.9	21.9	38.9	61.3	64.0	103.6	154.9	140.6	119.1	143.9	171.7	113.7	21%	-51%
small hydro	2.7	7.4	7.5	6.4	7.6	6.2	8.1	7.5	6.4	5.6	6.4	3.5	3.5	2%	0%
wind, solar & hydro	33.5	51.8	69.1	106.4	143.7	149.9	213.3	246.6	231.4	213.7	256.8	299.4	229.7		
wind, solar and small hydro as % of total	71%	71%	61%	67%	18%	84%	88%	88%	91%	91%	92%	96%	95%		

Note: Total refers to investments in biofuels, biomass and waste, geothermal and marine as well as wind, solar and small hydro power.

Source: UN Environment, the Frankfurt School-UNEP Collaborating Centre, and Bloomberg New Energy Finance, 2017, "Global Trends in Renewable Energy Investment 2017". Accessed at http://www.fs-unep-centre.org

Table 4: Global Trends in Renewable Energy by Major Economies/Regions ($ billion)

														CAGR %		
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2004-16	2015-16	2016 share
US	5.7	11.9	29.3	39.3	35.8	23.9	35.3	49.6	40.8	33.8	38.4	51.4	48.4	20%	-6%	20.0%
EU	25	33.1	46.8	67.4	81.3	82.5	43.9	123.8	88.9	59.4	53	58.1	59.8	8%	3%	24.7%
China	3	8.7	11.1	16.6	25.3	38.1	41.4	46	58.3	63.3	87.3	115.4	78.3	31%	-47%	32.4%
India	2.6	3.2	5.4	6.8	5.7	4.2	9	13.7	8	6.6	8.4	9.6	9.7	12%	1%	4.0%
ASOC	7.2	9	10.1	12.8	13.6	14.5	20	25.1	30.9	45.3	50.5	48.1	26.8	12%	-79%	11.1%
Total	47	72.7	112.7	159.3	181.4	178.3	243.6	251.2	255.5	234.4	278.2	312.2	241.8	15%	-29%	100.0%
	93%	91%	91%	90%	89%	92%	61%	103%	89%	89%	85%	91%	92%			
	43.5	65.9	102.7	142.9	161.7	163.2	149.6	258.2	226.9	208.4	237.6	282.6	223			

Note: ASOC refers to Asia and Oceania excluding China and India

Source: Frankfurt School-UNEP Centre/BNEF, 2017, " Global Trends in Renewable Energy Investment 2017", accessed at http://www.fs-unep-centre.org (Frankfurt am Main)

Table 4 above shows RE investments by 5 major economies or regions, typically accounting for 90% or more of global investments. China was the leading economy in the pace of growth in RE investments. Investments in China grew during this period by a remarkable compound growth rate of over 30%. By 2016, China accounted for almost a third of total global investments in RE technologies. The US was the location for the next most rapid investment growth in RE, at 20% annually over 2004 – 2016. In 2016, it accounted for 20% of global RE investments. Despite rapid growth in RE investments in the EU to 2011 (after a fall off in 2009 as a result of the financial crisis), the region's growth rate in RE investment over the 2004 – 2016 period is relatively low at 8% compounded annually, due to slower investments since 2011. In 2016, the EU accounted for 25% of total global investments in the sector. Both India and ASOC (Asia and Oceania excluding India and China) grew their investments in the sector by 8% annually over 2004 – 2016. In terms of cumulative investments over 2004 – 2016, the EU still holds first place, accounting for 32% of RE global investments. China comes in next at 23% and the US at 17%.

Table 5: Investments in RE in Top Ten Economies in 2016

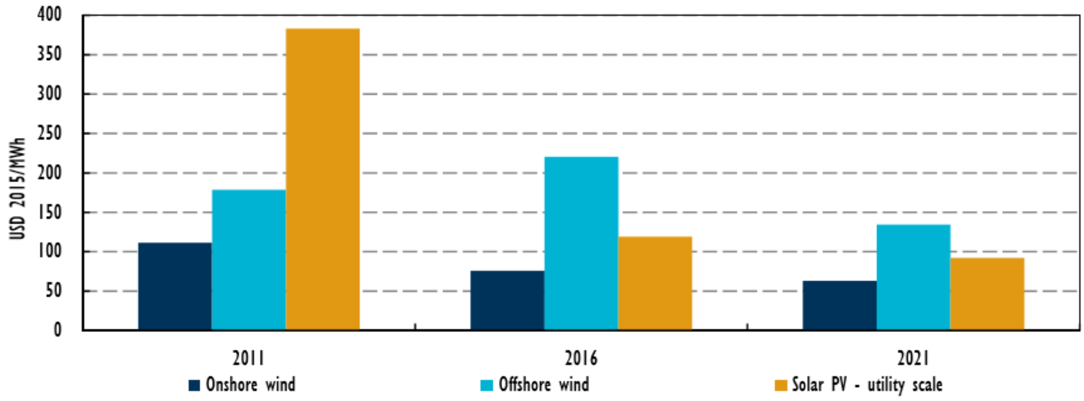
	$ Bn	Growth over 2015
China	78.3	-32%
United States	46.4	-10%
United Kingdom	24	-0.60%
Japan	14.4	-56%
Germany	13.2	-14%
India	9.7	0%
Brazil	6.8	-4%
Australia	3.3	51%
Belgium	2.9	179%
France	2.6	5%

Source: UN Environment, the Frankfurt School-UNEP Collaborating Centre, and Bloomberg New Energy Finance, 2017, "Global Trends in Renewable Energy Investment 2017". Accessed at http://www.fs-unep-centre.org

Among the top ten economies for RE investments (Table 5), four are APEC members: China; United States; Japan; and Australia. Among the non-OECD economies excluding China; and India; Thailand is in a leading position for RE investments, spending $1.4 bn in 2016. The Philippines comes next at about $1 bn, while Singapore; Viet Nam; and Chinese Taipei each accounted for $0.7 bn. Indonesia accounted for $0.5 bn. Thailand in particular has ambitious solar PV expansion plans, while Viet Nam has emerged as a significant wind power market. The Philippines has a range of RE investments in wind, solar, geothermal and small hydro although currently investments in solar dominate.

A striking statistic that comes out of the RE investment data examined in the tables above is the steep fall-off in investments across the board in 2016, across the RE technologies examined and across most economies or regions. Total investments on all RE technologies fell by almost 30% globally. China showed the highest fall-off in RE investments in 2016, at 47%, partly reflecting that economy's policy-driven slowdown as a result of over-investments leading to grid constraints. The ASOC region also showed an extreme drop of almost 80% in RE investments in 2016 reflecting a series of delays in large RE projects in economies such as South Africa; Mexico; Morocco; Chile; and Pakistan.[19] US investments fell by 6% while EU's investments grew slowly at 3% in 2016. If the 2016 data for investments in the three technologies is examined, the solar sub-sector showed the steepest decline. Solar investments in 2016 were lower than in 2015 by over 50% while investments in wind fell by 10%. The small hydro sub-sector showed no growth in 2016.

Figure 1: Global Weighted Average LCOEs for New Grid-connected Projects



Notes: LCOEs = levelised costs of energy; USD = US dollar; MWh = megawatt-hour. The values are indicative estimates of the global weighted average LCOE based on the *MTRMR* capacity and generation forecasts and may not represent specific developments in a given market. Offshore wind estimates include all transmission costs.

Source: IEA, "Renewable Energy Medium-Term Market Report 2016", p. 115.

Part of the explanation for the fall in RE investments in 2016 is explained by "a clear acceleration in cost reductions".[20] Figure 1 above shows the dramatic fall in generation costs between 2011 and 2016 for both solar PV (utility scale) and on-shore wind sub-sectors. In the International Energy Association's (IEA) latest study on RE technology trends, utility scale solar PV showed a remarkable fall of over 60% in the levelized cost of electricity (LCOE)[21] between 2011 and 2015 from about $380/MWh to about $120/MWh. In the case of onshore wind, the LCOE has come down from $110/MWh to $75/MWh over the same period. Looking forward into the medium term, the IEA expects utility scale PV generating costs to fall by a further 25% by 2021. In the case of on-shore wind, costs are also expected to fall by about 20% in IEA's medium term forecast. Offshore wind generation costs are expected to fall more steeply in the medium term, by about 40%.

---

[19] IEA, 2016, "Medium-Term Market Report Renewable Energy 2016", p. 18.

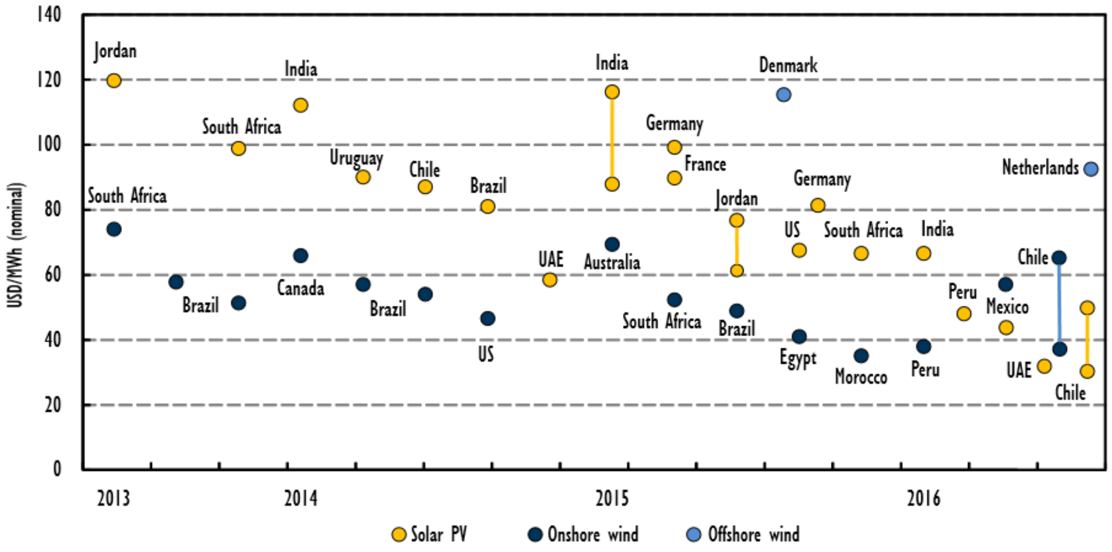
[20] IEA, 2016, "Medium-Term Market Report Renewable Energy 2016", p. 15.

[21] The LCOE is a measure of total cost (in present value terms) to build and operate a power-generating asset over its lifetime per unit of power output which is produced by the asset over that lifetime. The LCOE can also be used as an indicator of the average minimum cost at which electricity must be sold in order to break-even over the lifetime of the project. Note however that the LCOE is inherently deficient as a measure of cost of power generation across different technologies when some of those technologies produce power output intermittently (i.e. "when the sun shines or the wind blows"). For a critique of the LCOE concept in comparing power generation costs across different technologies, see Paul L. Joskow, 2011, "Comparing the costs of intermittent and dispatchable electricity generating technologies", Discussion Draft, MIT Sloan Institute, February 9, accessed at https://economics.mit.edu/files/6317 . In general, LCOE tends to understate the true cost per unit output of intermittent technologies such as solar and wind power.

Recent power purchase agreements for solar and wind power projects have been extremely competitively priced. The tender or auction awarded over the past year or so for RE projects (solar PV and onshore wind) in economies such as Chile; UAE; Mexico; and India have resulted in power purchase agreements (PPAs) in the range of $30/MWh to $45/MWh. Indeed, there has been a trend for governments to prefer auctions resulting in market-competitive PPAs rather than to support RE investments by offering government-determined financial incentives such as feed-in tariffs (FITs) or investment or production tax credits. Auctions with long term PPAs reduce investor risk premiums by providing revenue certainty. The participation of equipment manufacturers, financiers, insurance companies, O&M service providers and legal firms in preparing bid documents have also played a role in dynamic competition and low-priced PPA outcomes.

As shown in Figure 2 below, PPA that have been contracted over the past few years have declined in price significantly. Winning bids in India for instance have had PPAs that have decline in price by 30% in one year. The emirate of Dubai, in another example, achieved a very low bid in its first auction in 2015, at $30/MWh. It should be noted however that these auction results cannot strictly be compared with one another, as different auctions have different specific factors that determine the bid results. Factors such as agreed price escalations, low-cost financing arrangements, subsidies for land preparation and grid connections all play a role in determining winning bids. Despite these differences in the terms and conditions for RE power project auctions, it is clear that the results show very large reductions in LCOEs over the recent past. Currently, on average, LCOEs range from $60/MWh to $80/MWh for onshore wind, and $80/MWh to $100/MWh for solar PV projects, with the low bids for both technologies at around $40/MWh. In most cases, these low prices reflect not only technological progress in RE but are also due to cheap financing costs and good RE resources available in many of the locations which have offered these RE auctions (i.e. good all day insolation with little cloud cover for PV projects, and consistently good wind conditions for wind power projects).

Figure 2: Recent Announced Long-term Contract Prices for Renewable Power by Date of Announcement



Notes: Values reported in nominal USD; UAE = United Arab Emirates. US values are implied excluding tax credits; US wind value corresponds to Interior Region for commissioned projects in 2014. Other values reported correspond to projects that are expected to be commissioned over 2016-19. Offshore wind bid prices include transmission costs, which are estimated.

Source: IEA Renewable Energy Medium-Term Market Report 2016, p. 116, Fig 2.5

While the LCOE of RE technologies are already comparable to that of fossil fuel-based power generation in some economies which have favourable locations for RE resources such as solar insolation and wind speeds, it needs to be emphasized that a full assessment of costs of RE technologies in competition with coal and natural gas-based power generation must include the costs of integration (i.e. grid stability) and the relative value of power over the day (according to the daily demand load). As the share of intermittent RE technologies such as solar and wind power increases in total power output, RE increasingly loses its "system value" as integration increasingly imposes further system costs for grid stability and reliability. Despite low fossil fuel prices, investments in RE have been protected by generous policy supports already in place. Looking forward into the long term, the price trajectory of fossil fuels, future environmental policies and the problem of over-capacity in some economies facing lower growth in electricity demand (exemplified by the case of China) are key factors in the outlook for RE capacity growth.

As noted previously, investments in RE fell in 2016 from the previous year, yet new capacity in the sector increased as well, as Table 6 below shows. This is partially a result of falling costs in both solar PV and onshore wind power generation, allowing greater capacity additions for the same amount of investment. Nevertheless, the sharp slowdowns in investments especially in China in 2016 also played a role. The latter was an outcome of grid constraints that led to curtailments in generation from capacity that was rapidly built-up previously. Furthermore, the previous policy support via FITs in China expired in mid-2016.

It is apparent that the RE sector is no more "niche", i.e. adding capacity only at the margin. In 2016, over 55% of all new power generating capacity was accounted for by RE technologies, primarily solar PV and wind.[22] In IEA's medium term outlook, global capacity will grow by

[22] IEA, 2016, "Renewable Energy Medium-Term Market Report 2016", p. 18.

over 11% over 2015-21. Rapid growth in capacity is expected to continue in China and India, while other regions such Latin America, Middle East and North Africa, Sub-Saharan Africa and Russia are also expected to grow their RE capacity aggressively, albeit from a low base.

Table 6: **Medium Term Outlook on RE Capacity Growth by Major Regions/Economies (GW)**

	2015	2016	2017	2018	2019	2020	2021	2015-21
World	764.1	885.2	992.4	1098.8	1212.5	1335.6	1454.8	11.3%
North America	140.0	160.6	177.8	197.7	221.3	248.6	271.2	11.7%
United States	118.7	136.1	150.7	166.6	185.0	207.2	225.2	11.3%
Asia and Pacific	112.7	136.6	162.2	183.2	203.9	226.2	247.1	14.0%
India	37.0	45.7	55.6	66.0	77.5	90.4	102.3	18.5%
Japan	41.2	51.4	61.2	65.5	67.9	70.2	72.5	9.9%
China Region	182.9	232.1	270.3	309.5	350.4	392.8	438.9	15.7%
Europe	286.6	305.5	324.0	340.5	358.6	378.9	396.8	5.6%
Germany	93.8	99.5	104.8	109.0	113.0	117.3	121.9	4.5%
Latin America	31.3	36.8	40.3	45.8	50.8	55.8	61.2	11.8%
MENA	3.7	4.7	6.6	8.8	11.3	14.5	17.6	29.6%
Sub-Saharan Afri	5.1	6.6	8.4	10.2	12.3	14.5	16.9	22.1%
Eurasia	1.8	2.2	2.7	3.1	3.8	4.3	5.0	19.2%

Note: Total renewable capacity includes bioenergy, onshore and offshore wind, solar PV, solar CSP, geothermal, and ocean technologies. Hydropower and nuclear power is excluded.
Source: IEA, 2016, Data tables from "Medium Term Renewable Energy Market Report 2016".

3.1 SMALL HYDROPOWER

Small hydropower projects (defined as less than 10MW capacity) are extremely site specific in their cost structures. The topological, geological and hydrological characteristics of rivers determine technical parameters and costs. Other costs such as feasibility studies, socio-economic and environmental impact statements, transmission costs (for connecting to local grids), civil engineering and site preparation, licensing and permitting add to the overall costs of generation. Small hydropower installations include a large number of designs, layouts, equipment and materials. New and developing technologies, industry knowledge and design experience are essential in order to fully exploit local resources at competitive costs and without significant adverse environmental impact. The estimated generation costs of small hydropower projects can range from $20/MWh to $100/MWh.[23]

It is difficult to assess the social costs and benefits of hydro power. The option values of other water-related services such as irrigation, flood control, municipal water supply and leisure uses are complex and inter-related. While large hydro (which is a mature technology) dominate the RE sector, various challenges suggest that this sub-sector will not grow very much. The cost of labour and materials, the increased costs and political constraints related to large-scale re-settlement of people, and the environmental costs of large projects suggest that few governments are likely to readily undertake large hydropower projects. Small hydropower

[23] International Renewable Energy Agency (IRENA), 2015, "Hydropower: Technology Brief", February 2015, accessible at http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP_Tech_Brief_E06_Hydropower.pdf

projects, however, hold greater promise: lower environmental and re-settlement constraints, rapid advances in small turbine technology, and greater awareness of its role in rural development programs particularly in remote areas suggests that its use may grow in parts of Southeast Asia, Latin America and sub-Saharan Africa. In Southeast Asia, small hydropower has seen an increase in investment interest in Myanmar; Thailand; and Indonesia as part of the broader aim of rural development and poverty alleviation.[24]

3.2 ONSHORE AND OFFSHORE WIND

The development of large onshore wind farms in a number of economies has reduced the number of remaining sites with good wind resource potential, especially in more densely populated areas. Offshore wind power has seen increasing investment interest in some European economies are developing offshore wind power by taking advantage of the relatively shallow seabed adjoining the continent. As offshore wind speeds are typically higher than those on land, and create less turbulence, offshore wind is generally more efficient at generating power than onshore wind farms. However, offshore wind is a relatively newer sector and faces significantly higher costs related to working at sea. It therefore has higher construction, transmission connection and operation costs.

The estimated global production capacity in 2014 was 75GW, with the top ten manufacturers accounted for over 70% of the total. China and India manufacturing firms produce primarily for their domestic markets with rated turbine capacities of between 1 and 2 MW. European and United States manufacturing firms such as GE and Vestas mainly produce turbines at rated capacities of between 2 and 4 MW. The largest wind turbine manufacturing firm is Goldwind, a Chinese company, followed by Denmark's Vestas and the United States' GE.[25] Other large international manufacturers include European firms such as Siemens and Alstom. In China, the wind turbine market is dominated by about 3 to 5 large firms.

Technological developments have led to larger turbines, taller column heights and larger diameters for rotor blades.[26] Two major factors determine the economic feasibility of wind power generation: the cost of financing and the capacity utilization factor of the site chosen for the wind farm. In common with other RE technologies, wind power generation is highly capital intensive, and the costs of financing is therefore a key variable in determining profitability. And in common with solar PV, the generating output of wind farms depends on the quality of the RE resource – in this case, the consistency and speed of wind at the specific site chosen for the wind farm. Furthermore, in more densely populated economies such as Europe and parts of the Eastern seaboard of the United States, the high cost of land, construction and permitting adds to the upfront capital costs. Increasingly, local community opposition to wind farms has added significantly to costs in Europe and the United States.

---

[24] P. Chamamahattana, et al, 2005, "The small hydropower project as the important renewable energy", Asian Journal of Energy and Environment, Vol 6, No 2, pp. 139 – 144.
[25] IEA, 2016, op. cit., p. 127.
[26] IRENA, 2016, "Windpower: Technology Brief", March 2016, accessible at http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP_Tech_Brief_Wind_Power_E07.pdf

3.3 SOLAR PHOTOVOLTAICS (PV)

Solar PV cells convert sunlight directly into electricity. Currently, crystalline silicon (c-Si) and thin-film (TF) technologies dominate the global PV market. Crystalline silicon PV currently is the dominant technology with about 90% of the total PV market share. Manufacture of semiconducting material is accounted for by a few companies in the United States; Japan; Europe; and China. The technology-intensive production of PV cells requiring advanced manufacturing techniques takes place primarily in China; Germany; United States; and Japan. The manufacture of PV modules is a more labour-intensive process in which PV cells are covered by protective materials and frames to increase module strength is more diffuse, with over 1,000 companies worldwide producing solar PV modules. Over half of module manufacturing capacity is located in China although the latter has also invested in manufacturing capacity in other economies as well, primarily in Asia; Chinese Taipei and Malaysia account for approximately 30% of manufacturing capacity.[27]

At the local level, primarily smaller domestic companies install PV modules which including mounting inverters to connect the PV system to the grid and the final installation in residential or commercial buildings or in utility-scale projects. The cost of a PV module ranges between 30% and 50% of the total cost of the PV system. Remaining costs include the "balance of system" costs and installation costs. These costs are generally lower for utility-scale plants, which can be as low as 20% of total costs. For residential use, these costs can account for as much as 50-60% of total costs. For off-grid systems, these account for up to 70%, as they need to include battery storage and back-up power (such as diesel generators).[28]

The key determinants in the decision to invest in solar PV for installation include investment cost and module efficiency on the one hand and electricity tariffs and policy support on the other. The global PV market has grown faster than even the most optimistic projections. However, it is not clear whether the deployment of PV will slow down or continue to grow at the same as in the recent past years.

---

[27] IEA, 2016, op.cit., p. 134.

[28] International Renewable Energy Agency (IRENA), 2015, "Solar Photovoltaics: Technology Brief", January 2013, accessible at http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E11%20Solar%20PV.pdf

4. BUSINESS MODELS IN THE RE SECTOR

The term 'business model' is an informal phrase the meaning of which depends on user of the term and how he uses it. There is no generally accepted definition of what a business model is. At its simplest, it refers to how a person or business "makes money", say by buying or making a service or product cheaply and selling at a higher price. Peter Drucker defined the term as a set of "assumptions about what a company gets paid for"; these assumptions are about markets characteristics, technology and its dynamics, and about a company's strengths and weaknesses.[29] In the context of the RE sector, the IEA defines a business model as "the strategy to invest in RE technologies which creates value and leads to increasing penetration by RE technology or fuels".[30] It should be noted, however, that a distinction needs to be made between creating value for a firm as opposed to creating value for society in situations where revenues for the firm may be enhanced by policy-driven subsidies or other forms of support. To put it alternatively, while an economy's output is the sum of the value added of the firms operating in the economy by definition, subsidy support to any firm represents a redistributive transfer, not value addition. For the purposes of this paper, the term 'business model' is used to examine key resources and key activities of the value chain in the RE sector, in order to contribute towards understanding the scope of environmental services and in identifying challenges related to environmental businesses.

The business model of any firm is a function of two factors: the attributes of the market and regulatory environment within which it is operating. The key elements of the business model of firms generating electricity from RE sources are the characteristics of the specific product or service it offers, the mode of financing employed by the firm in carrying out its operation, the size or scale of the RE project and the attributes of the customers it is serving. Often, these elements are correlated. For instance, the scale of the RE project is determined by the market segment it is serving, so that a solar PV installation for a household will be small-scale while large-scale solar PV projects will be serving the larger commercial or industrial segments of the market. Larger still would be utility-scale projects which can supply electricity from RE resources directly to a utility-owned grid.

The revenue streams raised by a RE firm will also be a key element in its business model. The most significant revenue stream comes from selling electricity to the grid, either at a fixed regulated price (e.g. a guaranteed feed-in tariff or FIT) or at a market determined price. Depending on the regulatory environment, the project may also be able to generate and sell carbon emission reduction certificates or claim production or investment tax credits. Revenues of an RE firm may also be protected or enhanced by regulations that guarantee off-take of its power generated, for instance by Renewable Portfolio Standards (RPS) that requires retail sellers and utilities to procure a certain percentage of their electricity from eligible RE resources.

It is evident that business models can be characterized by a large number of criteria and examined across many dimensions, ranging from organizational structure and financing modes

---

[29] Peter F. Drucker, 1994, "The Theory of the Business", Harvard Business Review, September-October issue.
[30] L. Würtenberger, et al, 2012, "Business Models for Renewable Energy in the Built Environment", IEA – Renewable Energy Technology Deployment, accessed at http://iea-retd.org/wp-content/uploads/2012/04/RE-BIZZ-final-report.pdf

to characteristics of RE product or services on offer and the market segment being catered to. For the purposes of this study, perhaps the most productive approach is to identify key stakeholders and their contractual inter-relations in typical wind, solar PV and small hydro projects. This yields the most direct approach to uncovering key types of RES that are involved, their importance to the growth of RE sectors, and the impact of trade or investment restrictions on such services.

4.1 STAKEHOLDERS AND CONTRACTS IN THE RE SECTOR

Constructing and operating an RE power plant (or, for that matter, any other power generation facility) requires several contracts binding various stakeholders. They delineate the legal structure and constitute the means whereby rights and obligations are spelt out. They determine the incentive structure for the different stakeholders and constitute an essential part of optimal risk mitigation outcomes. Table 7 below provides an overview of the contractual framework.

Table 7: Stakeholders and Contractual Relations in RE Projects

Seller/Provider	**Products/Services**
Finance & Control	
Independent consultant	Project Site Survey Certification
Lenders	Loan Agreement
Equity Investors	Shareholders Agreement
Management	Management Contract
Project Control	
Relevant authorities	Planning Permission/Environmental Approval
Land owner	Long term lease agreement
Insurer	Risk insurance
EPC Contractor/Subcontractor	EPC Contract/Subcontracts
Equipment Vendor	Vendor Warranties
Operations	
O&M service provider	O&M contract
Interconnection with grid	Grid Operator connection rules
Fuel Supplier	Fuel supply contract
Vendor/Technology provider	Patented technology license payment contract
Marketing	
Power Supply	Power Purchase Agreement/Utility or Large Buyer
Relevant environmental agency	Feed-In Tariffs / Tax Credits / Other subsidies

Source: Literature survey and personal communication with solar PV company executives

Contracts dealing with finance and control include site survey requirements; loan agreements; shareholder's agreement that govern the capital structure and governance structure of the project company; and management contracts that define performance and incentives for managers of the project company. Contracts for the initiation and construction of the RE project refer to land lease agreements spanning the lifetime of the RE plant (typically 20 – 40 years); planning permissions and environmental assessments required by local authorities; insurance for certain types of insurable risks; engineering, procurement and construction (EPC) contracts which would include performance guarantees by the contractor and sub-contractors and equipment warranties by vendors.

4.2 UTILITY BUSINESS MODEL FOR RE INSTALLATIONS

For the operation of the RE installations, contractual agreements would be required for interconnection to the grid; long term off-take of the power output with a utility or consumer of the power supplied; wind or water turbine or PV module warranties and service agreements provided by the supplier of the equipment and commensurate with the operation and maintenance (O&M) of the RE plant; O&M services which would include clauses for performance, liability, compliance, remedies and dispute resolution; and operating licenses which would include payments by the RE project company for the use of patented technology. Contracts concerned with marketing aspects of the RE plant's output include PPAs, which incorporate details on power output sales to the purchaser; government agency certification that determines the basis on which the RE project company can qualify for FITs, and investment or production tax credits; and the sale of carbon credits or 'green' or RE certificates to government agencies or carbon markets that result from the production of power from RE sources as defined by the regulatory authorities.

Figure 3: Utility Business Model for a Power Company

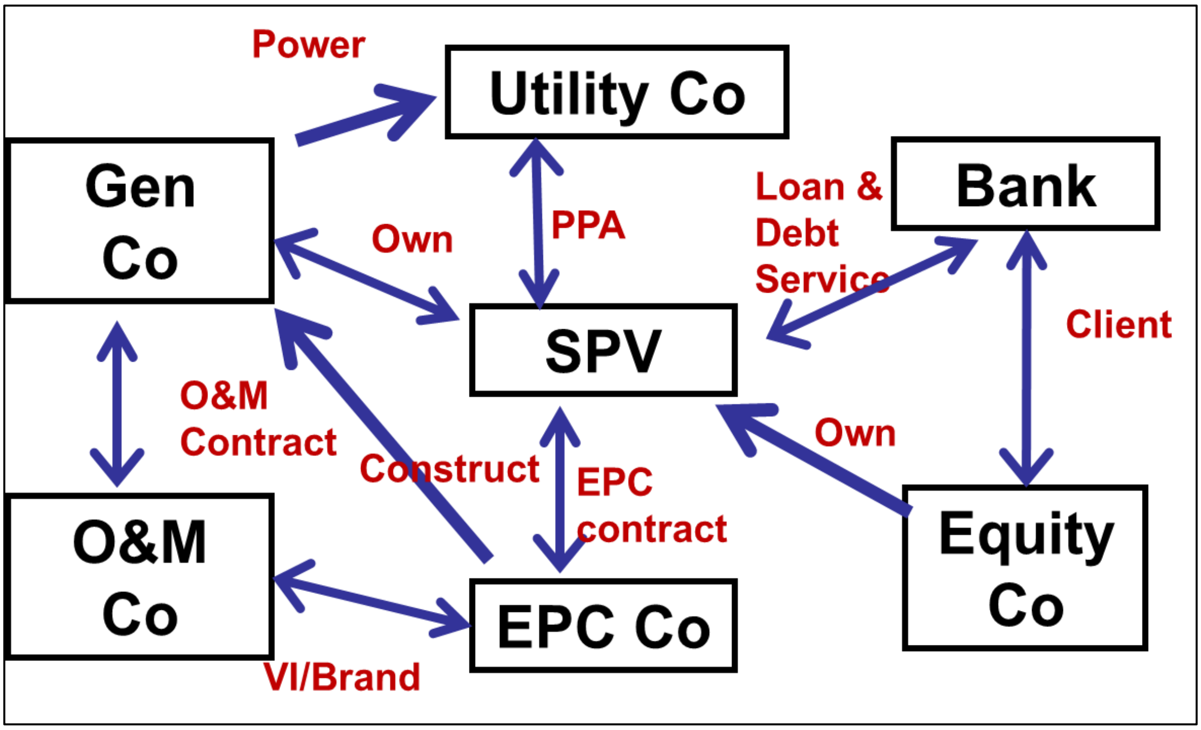


Figure 3 above provides a means to visualise a utility model set-up of a power plant, whether it is conventional fossil fuel-based or based on RE technology. At the heart of the business model lies the Special Purpose Vehicle (SPV) set up by the project promoter. The SPV is the central entity handling all contracts for funding with equity and debt investors. It also manages the construction and operation and maintenance (O&M) contracts, as well as the billing of end users. The SPV will typically have debt from a bank and equity from investors. The SPV may be owned by equity holders or it may be owned by the project promoter and pays dividends back to the equity holders. The SPV will have a contract with an engineering, procurement and construction (EPC) company to install the generating plant ("Genco"). The EPC company may provide O&M services itself, or may have a contract with an O&M company to provide O&M services for the generating plant. In cases where the technology is relatively complex or where brand reputation is important, the EPC company will usually provide O&M services itself. The Genco will deliver power to a utility company or a large industrial or commercial energy user.

Undergirding this model is the power purchase agreement (PPA) which provides revenue to the SPV for the supply of electricity to the buyer. In the RE sector, the PPA is usually not the only stream of revenues that the SPV will derive given that RE technologies are generally not competitive to the conventional alternatives of coal or gas-fuelled power plants. As previously mentioned, policy-driven benefits such as FITs, or production and tax credits may be critical for the project to be economically viable for the project promoter to cover his debt payments and yield a return to capital investments in the project. The full blown "utility model" as briefly described above address the technical complexity, economies of scale, capital costs, and funding requirements of RE projects involving medium to large-scale applications in wind or solar farms. For such grid-connected projects, the most appropriate ownership structure is usually a public–private partnership (PPP). It is generally implemented through build–own–

operate–transfer (BOOT), build-own-transfer (BOT) or build-own-operate (BOO) arrangements.

4.3 OTHER BUSINESS MODELS (LEASING, DEALER CREDIT AND ESCOs)

Smaller-scale projects usually involve lease or hire purchase and dealer credit sale business models.[31] This leasing model is one of the more common means of deploying solar PV technology for households and other small-scale applications. In the leasing model, users purchase equipment in instalments. A leasing company (lessor) -- which may be the equipment supplier or a financing company -- provides the equipment to the end user for a contracted period of time in exchange for regular payments. The lessor is obligated to procure, finance and install the equipment, and to maintain it during the contract period or throughout the operating life of the installation. At the end of the contract period, ownership of the equipment usually passes on to the lessee. Solar leasing is an established feature in Singapore, for example, where solar PV costs are already near parity to existing grid-supplied electricity tariffs.[32]

In the dealer credit business model, the equipment or system supplier provides the upfront capital to the user for the system. In this case, the 'dealer' (which might be a finance company or the RE technology company) supplies power together with a loan. The dealer collects down payments, monthly instalments and usually has recourse to recover both the loan and the installed RE equipment in case of default. The dealer or technology company is responsible for installation, customer training and after sales service. Ownership of the RE installation is transferred to the user at the end of the loan repayment period. As mentioned, this business model might involve a single company which provides both the technology and the finance or the technology company and the finance company are separate entities with a long-term partnership.

The delivered-service or product-service model is increasingly utilized in the RE sector for supplying power to the household, commercial and industrial sectors.[33] Several characteristics differentiate an energy service company (ESCO) from other RE business models. It guarantees energy savings (against a pre-defined historical baseline of the user) or provides the same level of energy service at a lower cost. Its performance guarantee involves the realized flow of energy savings from a project. It can stipulate that the energy savings will be sufficient to repay monthly debt service costs, or that the same level of energy service is provided at lower cost. ESCOs can provide finance, or assist in arranging financing, for the operation of an RE installation by providing a savings guarantee, and its remuneration is directly tied to the energy savings achieved. The ESCO model has been responsible for the rapid deployment of the residential solar market particularly in the US. The ESCO model, also known as the 'third-party' ownership model in the solar PV industry, represents 66% of the US residential solar

[31] Rolland, S., 2011, "Switched on to the Mini-grid", *Renewable Energy Focus*, May/June issue.

[32] Chan, Ye Wen, 2015, "New business models set to shake up solar energy sector", *Business Times* (Singapore) accessed at https://www.spring.gov.sg/NewsEvents/ITN/Pages/New-business-models-set-to-shake-up-solar-energy-sector-20150622.aspx

[33] EU Science Hub, undated, "Energy Service Companies", accessed at https://ec.europa.eu/jrc/en/energy-efficiency/eed-support/energy-service-companies

market and a considerable portion of the commercial market.[34] An accompanying PSU study on energy efficiency (EE) sector provides more details on EE business models.[35]

There are a range of other business models in the solar PV sub-sector. The 'self-financing' model is the simplest, where the consumer directly pays (or gets a loan) for the purchase, installation and maintenance of PV system. In this case, the user may benefit, depending on applicable regulations, from subsidized loans or other sorts of financial benefits available to those using RE sources to replace or reduce their use of fossil fuel-based power supply. In this model, the risks associated with the installation are borne by the user. This model is only applicable to "off-the-shelf" and "plug-and-play" technologies available in the solar PV sector. Households or small commercial or industrial users do not have the technical capability to adopt self-finance models for hydro or wind projects.

'On-bill financing' schemes offered by utilities in some states in the US provides property owners loans to pay for investments in clean energy upgrades through their utility. On-bill financing allows the utility to pay for the cost of the installing RE systems, which is then repaid on the utility bill. The advantage of this scheme is that utilities already have a billing relationship with their customers, as well as information about their energy usage patterns and payment history. In some on-bill repayment programs, the loan is transferable to the next owner of the home or building.

There are community-based business models being experimented in some jurisdictions in the US where customers purchase a share in a solar farm in return for credits to their electricity bills for the solar power produced under the scheme. Elements of these scheme seem promising for use in rural areas in developing economies. Yet another variant is "crowd funding" where 'green' investors put in money to crowdfund the installation of a solar PV system for a community or individual user in return for yield on their investment, while the user or users utilize the RE-based power supply by paying monthly instalments. This scheme has been carried out in Singapore with encouraging results.[36]

Relating Business Models to Trade in RES

As mentioned above, the key elements of the business model of firms generating electricity from RE sources are the characteristics of the specific product or service it offers, the mode of financing employed by the firm in carrying out its operation, the size or scale of the RE project and the attributes of the customers it is serving. Services associated with the production of electricity from renewable energy include:

- Site selection and pre-construction surveys for installing the necessary equipment;
- Design and engineering of the energy-producing facility;

[34] Litvak, Nicole, 2014, "US Residential Solar Financing 2014-2018". Boston, MA: GTM Research, cited in Tongsopit, S., et al (2015), 'Business Models and Financing Options for a Rapid Scale-up of Rooftop Solar Power Systems in Thailand', in Kimura, S., Y. Chang and Y. Li (eds.), *Financing Renewable Energy Development in East Asia Summit* Economies. ERIA Research Project Report 2014-27, Jakarta: ERIA, pp.79-136.

[35] APEC-PSU, 2017, Sector Study on Environmental Services: Energy Efficiency Businesses. Singapore: APEC Secretariat Policy Support Unit

[36] Khew, Carolyn, 2016, "Bukit Timah penthouse gets power from the sun", *Straits Times*, October 17, 2016.

- Installation and construction of the facility;
- Upgrading, operation or maintenance of the facility over the contract period.

A typical large-scale, renewable-energy-based electricity generating facility as described above in the "utility" business model comprises the generating unit itself (an array of photovoltaic modules, one or more wind turbines, a water turbine and generator, etc.) plus associated electrical transformers and switchgear ("balance of systems"). Suppliers of internationally traded services range from small and medium-sized suppliers of consulting and engineering services to multinational companies that provide the gamut of services needed for large and complex turn-key projects. Many of the suppliers specialise in the particular technologies, such as wind or hydro energy. The larger companies typically operate through local subsidiaries so the predominant mode of supply is mode 3 (establishing a commercial presence in the host economy), with accompanying mode 4 (professionals temporarily working abroad). Mode 1 supply has become more common, particularly for wind-power projects in remote locations (e.g. remote monitoring services provided from abroad to foreign clients) as software and information technologies continue to grow in importance in the RE sector. Reflecting the fact that RE technologies are typically located higher along the "complexity ladder",[37] mode 2 has also become increasingly relevant for training associated with design, construction and operation of RE facilities (e.g. engineers travelling abroad to receive training).

Business models in small-scale solar PV installations lie at the other end of technological complexity in RE projects. In these business models, domestic firms often provide integrated solutions to the household and commercial sector that includes project financing, design, installation and maintenance services with off-the-shelf imported PV modules and other "balance of systems" components. In these cases, civil and electrical work as well as other services are provided by local firms who employ technicians that are either accredited locally or trained abroad. In less developed economies which have weak vocational training and accreditation institutions and which impose strict visa and employment rules on technical, engineering and consulting services provided by foreign nationals, such business models face binding constraints. For instance, the lack of skilled technicians to design and install RE equipment in less developed ASEAN economies such as Myanmar and Cambodia are cited as barriers to increased deployment of RE.

[37] Sauvage, Jehan and Timiliotis, Christina, "Trade in Services Related to the Environment", op. cit., p. 9.

Table 8: Restrictions on RES Trade and Business Models

	Impacts on Business Models	
Examples of Restrictions affecting trade in RES (primarily Mode 3 and 4)	**Utility model**	**ESCOs, leasing and dealerships (SMEs)**
Foreign equity limits and legal form of companies	√√	√
Nationality or residency requirements for accreditation of certain types of services	√√	√
Restrictions on Land Acquisition	√√	n/a
Limited eligibility for subsidies or other financial benefits (tax or investment credits)	√√	√√
Government procurement rules favouring domestic firms	√√	n/a
Costly and time consuming visa and work permit requirements	√√	√
Limitations on duration of stay by foreign personnel	√√	√
Local content requirements	√√	n/a
	Key	
	√√	very important
	√	less important but still a factor of consideration
	n/a	not applicable or not very relevant

Source: Adapted from literature survey and interviews

While barriers to trade in RES are covered in the section below, Table 8 above gives an overview of the implications of restrictions on trade in RES for two broad groups of business models: the utility model which usually covers large scale RE projects and the group of models that are typically constituted by small and medium-sized enterprises (SMEs). Both foreign equity limits and residency or nationality requirements for accreditation of certain types of services (e.g. technical engineering or design consultancy) are critical to large RE deployment projects as described in the "utility" business model. In particular wind projects and utility-scale solar PV projects promoted by the large firms such as GE or Siemens are far more effected by restrictions on equity stakes and the ability to employ third economy skilled personnel for short durations.

In contrast, SMEs that engage in smaller scale solar PV projects in the household and commercial or industrial segments are less effected by such constraints as they tend to be locally-owned and staffed by locally-accredited technical personnel. Given the standardization of many components of solar PV installation and operation in the household and small commercial or industrial segments, it has become easier for SMEs to source local staff with the requisite skills in the relatively more developed economies with a sufficient base of vocational and accreditation institutions. Furthermore, given their smaller-scale and local equity ownership, restrictions on land acquisition, government procurement and minimum local content are not directly relevant to business models adopted by SMEs.

Both utility scale as well as SME business models in both OECD and non-OECD economies have generally depended on the eligibility for government-financed subsidies to make the RE deployment feasible, and significant resources have been spent in economies which aggressively supported solar PV development early on, such as Germany, Spain, Australia and Thailand. However, as pointed out in the section on RE sector characteristics, the steep fall in solar PV module prices since 2015 and the increasing frequency of reverse auctions to commission large solar PV projects around the world has led to a lower dependence on subsidy eligibility as utility scale solar PV costs in some regions well-endowed with RE resources have come down to levels competitive with fossil fuel-based energy generation.

In relating trade in RES with business models, it is important to note that the demarcations between different business models are imperfect, and adverse impacts on one may also affect others. For example, analysis of company-level data supports a negative correlation between trade restrictions imposed by economies on environmentally-related services and their exports of core environmental services.[38] Thus, in attempting to protect domestic firms from foreign competition by restrictions on trade in RES, the same restrictions work to hobble domestic firms from being able to compete in export markets for RES.

In general, all business models are affected by restrictions on commercial presence (mode 3) when one considers the broad set of services such as design and engineering consulting and construction that form critical inputs into RE projects. Under mode 3, foreign subsidiary companies would be expected to draw on local labour markets wherever possible. However, if there are constraints on the requisite skills needed in the host economy, the investment in RE deployment will fail to take place. According to the OECD's STRI database, accreditation restrictions requiring managers in engineering firms to be locally-licensed professionals adversely affects the transfer of skills that require the temporary presence in the host economy of skilled consultants and engineers from abroad (mode 4).[39] Given that RES are inherently skill and labour-intensive, obstacles to the movement of skilled staff is a strong barrier to trade in RES.

[38] Savage and Timiliotis, "Trade in services related to the environment", op. cit.
[39] OECD, 2017, "OECD Services Trade Restrictiveness Index", Trade Policy Note, June, accessed at http://www.oecd.org/tad/policynotes/STRI%20trade%20policy%20note.pdf

5. BARRIERS TO TRADE IN RES

Among the major hurdles to a free trade agreement in EGS has been in the "trade remedy" clause: while normal tariffs are covered by the APEC declaration, special tariffs imposed through what is termed as "trade remedies"—antidumping (AD) duties, countervailing duties (CVD), and "safeguard actions"—are not. Both, CVD and AD are applied with increasing frequency to international trade in EGS, imposed to offset foreign subsidies or to penalize price discrimination practices which cause material harm caused to domestic producers. In contrast to ADs and CVDs, the definition of "safeguard actions" is more expansive. Safeguard actions are designed to deal with unexpected circumstances arising in the course of "normal" trade which can be imposed even if there has been no claim of unfair trading practice; the only requirement would be that imports have increased to such as extent that they cause material injury to domestic producers.[40] As the "material injury" standard is considered weaker, and because ADs and CVDs are economy-specific, they are typically easier to impose. WTO rules require that for the trade remedy clause to apply, there is a demonstrable link between the change in trade volume and the imposition of either AD or CVD. The existence of a causal link is normally determined by an administrative body in the importing economy invoking the AD or CVD remedy.[41]

Over recent years, trade remedy actions on EGS have mounted. The Wind Tower Trade Coalition, an association of U.S. producers of wind towers, brought an AD/CVD complaint against imported wind towers imported in 2011. The U.S. Commerce Department declared a preliminary decision in December 2012 which found both subsidization and dumping in relation to Chinese imports and imposed an antidumping tariffs and countervailing duties. The Commerce Department also established a separate antidumping duty on Vietnamese wind tower exporters.[42] In October 2011, a group of U.S. solar panel manufacturers accused Chinese solar panel companies of dumping products in the United States. The Commerce Department opened an investigation and announced the final ruling in 2012 to impose antidumping tariffs on Chinese producers.[43] In Europe, a Belgian industry association, filed a "dumping" complaint against Chinese solar panels, cells, and wafers in 2012. Given the large volume of Chinese solar panel exports to Europe, this was the biggest (by value) antidumping investigation in WTO history.[44] In June 2013 the EU announced that it would impose antidumping levies on Chinese solar products. In August 2013, the EU reached an agreement with China to suspend antidumping duties on Chinese manufacturers on condition that the latter would not sell solar panels in the EU at a price below an agreed floor price.[45] There have been other WTO disputes

[40] Thomas J. Prusa, undated, "Trade Remedy Provisions", World Bank Resources databank, accessed at http://siteresources.worldbank.org/INTRANETTRADE/Resources/C9.pdf

[41] WTO, undated, "Understanding the WTO: The Agreement: Anti-dumping, subsidies, safeguards: contingencies, etc", undated, accessed at https://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm8_e.htm

[42] Doug Palmer, 2012, "U.S. Slaps Duties on China Wind Towers, High-Level Talks Begin," Reuters, December 18, 2012, accessed at http://www.reuters.com/article/2012/12/18/us-usa-china-trade-id USBRE8BH17K20121218

[43] Diane Cardwell and Keith Bradsher, 2012, "U.S. Will Place Tariffs on Chinese Solar Panel," New York Times, October 10, 2012, accessed at http://www.nytimes.com/2012/10/11/business/global/us-sets-tariffs-on-chinese-solar-panels.html

[44] Keith Bradsher, 2012, "Europe Investigates Chinese Solar Panels," New York Times, September 6, 2012, accessed at www.nytimes.com/2012/ 09/07/business/global/eu-investigates-chinese-solar-panels.html

[45] Juergen Baetz, 2013, "EU Slaps Levies on Chinese Solar Panel Imports," USA Today, June 4, 2013, accessed at

in trade in solar panels, polysilicon (a key material used in PV cells) and PV solar cells involving China; United States; Europe; Korea; and India.[46]

It is important to note that the number of AD/CVD cases far exceeds the small number of disputes that have been launched at the WTO. Trade remedies yield a faster and direct response to perceived unfair industrial policies compared to WTO dispute resolution. Two leading trade economists at an Ad hoc Expert Group Meeting on Trade remedies in Green Sectors in 2014 presented the results of a survey of AD/CVD cases in the RE sector from 2008 to early 2014 found 26 anti-dumping cases and 15 parallel subsidy investigations. Six economies pursued investigations: Australia, China, the European Union, India, Peru, and the United States. The EU initiated the greatest number of AD/CVD cases (18 cases); the US and China accounted for 8 and 5 of the cases initiated, respectively. The RE products targeted biofuels (16 cases), solar energy products (18 cases) and wind energy products (7 cases). [47] It should be noted that there have been no WTO disputes involving RE services. However, given the strong link between RE goods and RE services, trade restrictions on environmental goods inevitable affects trade in environmental services. Put alternatively, those who are shut out of trade in RE products are also shut out of the related sales in RES.

Perhaps the most critical barrier to trade in RE products and services is presented by local content requirements (LCR). LCRs act as a barrier to trade in both technologies and services for renewable energy. For example, LCRs require renewable energy projects like wind or solar farms to include a minimum share of goods or services of domestic origin, or in some cases these projects require a ratio of local content in order to qualify for FIT support.[48] There are few trade or investment barriers to RES specifically;[49] as noted previously most economies are signatories to GATS but GATS provides no separate listing of various services in the RE sector. LCRs are directed at the RE sector in policy efforts, particularly in developing economies, as a means of promoting domestic manufacturing and related capacity as well as employment in what are considered to be new, technology-intensive industries such as wind and solar power.[50] While the economics literature has widely noted the deficiencies of the "infant industry" argument for protection, LCRs still play a critical role in the industrial policy of many

---

www.usatoday.com/story/money/business/2013/06/04/eu-tariffs-chinese-solar/2387951/ ; James Kanter and Keith Bradsher, 2013,"Europe and China Agree to Settle Solar Panel Fight," New York Times, July 27, 2013, accessed at
www.nytimes.com/2013/07/28/business/global/european-union-and-china-settle-solar-panel-fight.html

[46] Simon Lester and K. William Watson, 2013, "Free Trade in Environmental Goods: The Trade Remedy Problem", Cato Institute, Free Trade Bulletin No. 54, August 19, 2013

[47] Gary Hufbauer & Cathleen Cimino, 2014, "Trade Remedies in Renewable Energy: A Global Survey", presentation to UNCTAD Ad hoc Expert Group Meeting on Trade remedies in Green Sectors Geneva, 3 - 4 April 2014.

[48] Ankit Panda, 2014, "US Disputes Indian Solar Power Policy At WTO", The Diplomat, February 12.

[49] Thus, for instance, the USITC reports that "...[t]here are few barriers that specifically affect trade and investment in the wind, solar, biomass, geothermal, or ocean energy production or services sectors. However, regulatory barriers that apply to incidental sectors, such as professional licensing provisions that apply in the consulting and engineering industries, as well as investment measures, land-use provisions, and limitations on movement of persons that apply to trade and investment in all sectors, may affect trade and investment in the renewable energy industry". USITC, 2005, "Renewable Energy Services: An Examination of U.S. and Foreign Markets" (Investigation No. 332-462, USITC publication 3805, October)

[50] Peszko, Grzegorz, and Janina Ketterer. 2013, "Local Content Requirements for Renewable Energy: An Unnecessary Evil." European Bank for Reconstruction and Development (EBRD) Blog, November 23, 2013 accessed at http://www.ebrdblog.com/wordpress/2012/11/local-content-requirementsfor-renewable-energy-an-unnecessary-evil/ .

economies. As noted previously, suppliers of RE technologies also supply the associated services needed to deploy such technologies. Thus, LCRs not only block RE technology providers from being able to sell their products but also the critical services they provide. Some of the largest emerging markets for RE technologies and services in economies such as South Africa, Canada, India, Greece, Italy, and Turkey apply LCRs.[51]

LCRs can affect trade adversely in EGS in several other ways. Some economies require foreign RE equipment manufacturers or service providers to have their staff to be citizens of the host economy (a mode 4 restriction), or mandate that foreign firms have local partners or majority local ownership (mode 3 restriction). LCRs can also include price preferences awarded to domestic firms that bid on government procurement contracts or government-sanctioned RE projects, mandatory minimum percentages required for the domestic goods and services used in production, import licensing procedures designed to deter foreign suppliers, and discretionary rules that encourage domestic firms and disadvantage foreign firms. LCRs can also impose cumbersome project approval processes, unique or economy-specific standards, or certifications for products, processes or staff that do not recognize foreign providers of renewable energy services.[52] Furthermore, visa and labour regulations may also be tailored for the specific purposes of protecting domestic industry generally, or specific sectors of the domestic economy. The cost of LCRs to the global economy are huge. According to one estimate, LCRs on global trade reduce global trade by about $93 billion annually.[53] There are no available estimates of the adverse impact of LCRs on the trade in EGS that this author is aware of. However, one study of the impact of AD/CVD actions that have been increasing taken up in recent years in the RE sector estimates that $14 billion of trade in RE products is lost annually and about $68 billion over 5 years, with concentrated effects on solar energy products.[54]

5.1 ISSUES TO CONSIDER IN OVERCOMING BARRIERS TO TRADE IN EGS

At the broadest level, three policy postures should be adopted by APEC member economies (and more widely by WTO members) on the trade and environment front. First is the need to focus on efforts in various trade fora to liberalize trade in RE services which would promote both economic and environmental benefits to trading partners in the global economy. Second would be intensified negotiation efforts in the APEC and WTO trade agendas to expand the definition of environmental services to include the many critical services that play an integral role in the deployment of cleaner energy technologies. Given that the statistical systems in place and the definitions adopted with respect to traded goods and services are ill-suited to gather accurate and useful data on the trade in EGS, more resources should be expended by the

[51] Hufbauer, Gary, et al, 2013, "Local Content Requirements: Report on a Global Problem", Peterson Institute for International Economics, accessed at http://files.publicaffairs.geblogs.com/files/2014/08/Local-Content-Requirements-Report-on-a-Global-Problem.pdf

[52] Gary Clyde Hufbauer, Jeffrey J Schott, Cathleen Cimino-Isaacs, 2013, "Local Content Requirements: A Global Problem", Peterson Institute of International Economics, Washington DC, US.

[53] Cathleen Cimino, Gary Clyde Hufbauer, and Jeffrey J. Schott, 2014, "A Proposed Code to Discipline Local Content requirements", Policy Brief Number Pb14-6, February.

[54] Gary Hufbauer & Cathleen Cimino, 2014, op. cit., "Trade Remedies in Renewable Energy: A Global Survey".

.

relevant multilateral agencies in the systematic collection of data on firms and economies that are involved in the trade in environmental services in the widest sense.

At a more disaggregated level, there should be strengthened negotiating efforts in either doing away with non-tariff barriers such as local content requirements, or at least replacing them with explicit tariffs so that the costs of protection are transparent. If non-price barriers such as LCRs cannot be altogether displaced, APEC member economies could adopt sunset clauses so that they are discontinued over a period of time (say over five to ten years). LCRs clearly reduce competition by excluding foreign suppliers, thereby raising the cost of RE for the host economy. Not only would the burden of protection (which falls on both, the host economy and the firms providing EGS) be time bound, and hence less deleterious, but it would also serve to ensure that "infant industries grow up" as they prepare to face external competition during the time-bound period of mandated protection.

Given that costs of non-price based protection such as LCRs balloon over time as the lack of international competition lead to the entrenchment of low-productivity firms (that typically expend resources towards maintaining such protection by lobbying and rent-seeking activity), policy makers should strive to make a clear distinction between value-adding local content that arises out of competition and mandated local content standards afforded by protection. Cost factors act as strong incentives for foreign providers of EGS to localize business as fast as possible. Local training, skills development and vocational institutes create the basis for value-added localization as fast as possible.

Since various mandatory technical standards are imposed by governments on firms operating in their jurisdiction, they are difficult to harmonize between economies. Member economies may consider adopting mutual recognition agreements for assessing national conformity to agreed international standards. Member economies may also consult with each other in confidence before establishing new standards.

6. CONCLUSION

Freer trade in environmental goods and services have considerable potential to promote sustainable development by lowering the costs of preventing and abating pollution as well as meeting targets in mitigating greenhouse gas emissions. As already noted, most liberalization efforts in forums such as the WTO and APEC to date have sought to overcome barriers to trade in environmental goods, and less effort has been expended to liberalizing trade in environmental services. It is apparent that the range of services that go into making RE deployment projects viable are much wider than the traditional “core” of environmental services as defined by division 94 in the UN’s CPC system.

As we have seen, trade in environmental goods and services are inextricably linked and trade in services such as scientific and technical consulting services, professional services, and construction and engineering services are critical to RE projects in the solar PV, wind and small hydro sectors. Barriers to trade in RES slow the deployment of technologies utilizing RE technologies such as solar PV, wind and hydro-power. The installation and operation of RE equipment can be technically complex processes, and require host economies to possess specific knowledge and skills which are costly to acquire.

Even though RES have much evolved over the past few decades with the development of new RE technologies such as those considered in this paper, the traditional definition of environmental services as those offered by municipal authorities that emerged out of the WTO’s Services Sectoral Classification List (the “W/120” list) drawn up in 1991 for the purpose of negotiating GAT (such as water treatment, collection of hazardous and non-hazardous waste, remediation, sanitation and similar services) has remained without any updates in the classification systems in place. Thus, with respect to the RE sector focused in this study, one recent report remarked that “the only explicit reference made to renewable energy in version 2 of the CPC is found in ‘engineering services for power projects’ (CPC 2 83324)”.[55]

Economies have generally made relatively few commitments in environmental services in GATS, and many economies have made no commitments under Mode 1. More liberalization of trade in RES seems to have occurred in various regional trade agreements (RTAs). According to one OECD study, about 40% of all market-access commitments for environmental services in surveyed RTAs had been improvements on prior GATS commitments.[56] Given the rapid growth in the RE sector, and the increasing importance of trade in RES, it is to be hoped that increased efforts are applied in three key directions.

Firstly, trade policy analysts and negotiators need to revise (and expand) the scope of what ought to be liberalized under the category of “environmental services”, in keeping with the fast-evolving developments in the RE sector. Many services that are not currently considered as “environmental” are in fact critical inputs to RE projects. It is important that negotiators consider how these services “cluster” and constitute an inter-related set that cohere and play an

---

[55] Monkelbaan, Joachim, 2013, “Trade in sustainable energy services”, International Centre for Trade and Sustainable Development (ICTSD), Geneva, cited in Sauvage and Timiliotis, op cit. p. 14.

[56] Miroudet, S, Suavage, J., and Sudreau, M., 2010, “Multilateralising regionalism: How preferential are services commitments in regional trade agreements?”, *OECD Trade Policy Papers*, No 106, OECD.

integral role in RE projects. Secondly, on the basis of improved definitions and a clearer scope of statistical coverage, more empirical evidence and analysis need to be marshalled to help negotiators and policy makers be aware of the benefits of freer trade in renewable energy services. An example of this is along the lines of work initiated by the OECD to quantify the restrictions on trade in services.

Third is the need to push liberalization efforts in Modes 3 and 4 both of which hold great potential for encouraging SMEs in many emerging economies to fully participate in global value chains related to RE goods and services. Rapid changes in IT and RE technologies also suggest that Mode 1 may increasingly be important to trade in RES, as remote sensing and other IT-based ‘real time” services become increasingly common across borders.

Liberalization of trade in RES benefit both importers and exporters, given the evidence that trade restrictions on services undermine the competitiveness of firms of the host economies while increasing the costs of pollution abatement and environmental improvement. Ultimately, international trade in services and the movement of people need to be liberalized in a coherent and coordinated manner for the benefit of economies in their development and environmental goals.

GLOSSARY

AD	Antidumping duties
CPC	Central Product Classification (United Nations)
CVD	Countervailing duties
EGS	Environmental goods and services
EPC	Engineering, procurement and construction
ESCO	Energy service company
Genco	Electricity generation company
HS	Harmonized system
ICTSD	International Centre for Trade and Sustainable Development
IEA	International Energy Agency
IRENA	International Renewable Energy Association
LCR	Local content requirements
LED	Light emitting diodes
O&M	Operations and maintenance
OEM	Original equipment manufacturer
PPA	Power purchase agreement
PV	Photovoltaics
RE	Renewable energy
RES	Renewable energy services
RTA	Regional trade agreement
SMEs	Small and medium-sized enterprises
SPV	Special purpose vehicle
UN	United Nations
WTO	World Trade Organization

BIBLIOGRAPHY

APEC, "20th APEC Economics Leaders' Declaration, Vladivostok, Russia. Annex C: APEC List of Environmental Goods", 8 September 2012, accessed at http://apec.org/Meeting-Papers/Leaders-Declarations/2012/2012_aelm/2012_aelm_annexC

APEC News release, 2016, "APEC Cuts Environmental Goods Tariffs", 28 January.

APEC Policy Support Unit, Survey of Regulatory Measures in Environmental Services, http://publications.apec.org/publication-detail.php?pub_id=1769 ; "CPC94" refers to "Sewage and waste collection, treatment and disposal and other environmental protection services", see United Nations, 2015, "Central Product Classification (CPC) Version 2.1", accessed at https://unstats

Baetz, Juergen, "EU Slaps Levies on Chinese Solar Panel Imports," *USA Today*, June 4, 2013, accessed at www.usatoday.com/story/money/business/2013/06/04/eu-tariffs-chinese-solar/2387951/

BP, "BP Statistical Review of World Energy 2016" accessed at https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf

Bradsher, Keith, "Europe Investigates Chinese Solar Panels," *New York Times*, September 6, 2012, accessed at www.nytimes.com/2012/ 09/07/business/global/eu-investigates-chinese-solar-panels.html

Cardwell, Diane and Bradsher, Keith, "U.S. Will Place Tariffs on Chinese Solar Panel," *New York Times*, October 10, 2012, accessed at http://www.nytimes.com/2012/10/11/business/global/us-sets-tariffs-on-chinese-solar-panels.html

Chan, Yi Wen, 2015, "New business models set to shake up solar energy sector", *Business Times (Singapore)*, accessed at https://www.spring.gov.sg/NewsEvents/ITN/Pages/New-business-models-set-to-shake-up-solar-energy-sector-20150622.aspx

Chamamahattana, P. et al, 2005, "The small hydropower project as the important renewable energy", *Asian Journal of Energy and Environment*, Vol 6, No 2, pp. 139 – 144.

Drucker, Peter F., 1994, "The Theory of the Business", *Harvard Business Review*, September-October issue.

EU Science Hub, undated, "Energy Service Companies", accessed at https://ec.europa.eu/jrc/en/energy-efficiency/eed-support/energy-service-companies

Hufbauer, Gary & Cimino, Cathleen, 2014, "Trade Remedies in Renewable Energy: A Global Survey", presentation to UNCTAD Ad hoc Expert Group Meeting on Trade remedies in Green Sectors Geneva, 3 - 4 April 2014.

International Energy Agency (IEA), 2016, "Medium-Term Market Report Renewable Energy 2016".

International Renewable Energy Agency (IRENA), 2015, "Hydropower: Technology Brief", February 2015, accessible at http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP_Tech_Brief_E06_Hydropower.pdf

International Renewable Energy Agency (IRENA), 2015, "Solar Photovoltaics: Technology Brief", January, accessible at http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E11%20Solar%20PV.pdf

International Renewable Energy Agency (IRENA), 2016, "Wind-power: Technology Brief", March, accessible at http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP_Tech_Brief_Wind_Power_E07.pdf

International Renewable Energy Agency (IRENA), 2015, "Hydropower: Technology Brief", February, accessible at http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP_Tech_Brief_E06_Hydropower.pdf

Joskow, Paul, 2011, "Comparing the costs of intermittent and dispatchable electricity generating technologies", Discussion Draft, MIT Sloan Institute, February 9, accessed at https://economics.mit.edu/files/6317

Kanter, James and Bradsher, Keith, 2013, "Europe and China Agree to Settle Solar Panel Fight," *New York Times*, July 27, 2013, accessed at www.nytimes.com/2013/07/28/business/global/european-union-and-china-settle-solar-panel-fight.html

Khew, Carolyn, 2016, "Bukit Timah penthouse gets power from the sun", *Straits Times*, October 17, 2016.

Lanz, Rainer and Maurer, Andreas, 2015, "Services and Global Value Chains: Some Evidence of Manufacturing and Services Networks", *WTO Working Paper* ERSD-2015-03.

Lester, Simon and Watson, William K., 2013, "Free Trade in Environmental Goods: The Trade Remedy Problem", Cato Institute, *Free Trade Bulletin*, No. 54, August 19, 2013

Litvak, Nicole, 2014, "US Residential Solar Financing 2014-2018". Boston, MA: GTM Research, cited in Tongsopit, S., et al (2015), 'Business Models and Financing Options for a Rapid Scale-up of Rooftop Solar Power Systems in Thailand', in Kimura, S., Y. Chang and Y. Li (eds.), *Financing Renewable Energy Development in East Asia Summit Economies*. ERIA Research Project Report 2014-27, Jakarta: ERIA, pp.79-136.

Miroudet, S, Suavage, J., ad Sudreau, M., 2010, "Multilateralising regionalism: How preferential are services commitments in regional trade agreements?", OECD Trade Policy Papers, No 106, OECD, Paris.

National Board of Trade, 2014, "Making Green Trade Happen – Environmental Goods and Indispensable Services", Stockholm.

Palmer, Doug, 2012, "U.S. Slaps Duties on China Wind Towers, High-Level Talks Begin," Reuters, December 18, 2012, accessed at http://www.reuters.com/article/2012/12/18/us-usa-china-trade-id USBRE8BH17K20121218

Panda, Ankit, 2014, "US Disputes Indian Solar Power Policy at WTO", *The Diplomat*, February 12.

PC Control, 2008, "PC Control for wind turbines", PC Control Special Edition, February 2008 issue accessed at http://www.beckhoff.com/english/pdf/applicat/pcc_0208_Special_PC_Control_for_wind_turbines_e.pdf

Peszko, Grzegorz, and Ketterer, Janina, 2013, "Local Content Requirements for Renewable Energy: An Unnecessary Evil." European Bank for Reconstruction and Development (EBRD) Blog, November 23, 2013. Accessed at http://www.ebrdblog.com/wordpress/2012/11/local-content-requirementsfor-renewable-energy-an-unnecessary-evil/ .

Prusa, Thomas J., "Trade Remedy Provisions", undated, World Bank Resources databank, accessed at http://siteresources.worldbank.org/INTRANETTRADE/Resources/C9.pdf

Rolland, S., 2011, "Switched on to the Mini-grid", *Renewable Energy Focus*, May/June issue.

Sauvage, Jehan and Timiliotis, Christina, 2017, "Trade in Services Related to the Environment", *OECD Trade and Environment Working Papers* 2017/02.

Smil, V., "Examining energy transitions: a dozen insights based on performance", *Energy Research and Social Science*, 22 (2016), 194-197.

UN Environment, the Frankfurt School-UNEP Collaborating Centre, and Bloomberg New Energy Finance, 2017, "Global Trends in Renewable Energy Investment 2017". Accessed at http://www.fs-unep-centre.org

United Nations, undated, Department of Economic and Social Affairs Statistics Division, Statistical Papers Series M No. 77, Ver.2.1, "Central Product Classification (CPC) Version 2.1" accessed at https://unstats.un.org/unsd/cr/downloads/CPCv2.1_complete%28PDF%29_English.pdf

United States International Trade Commission (USITC), 2013, "Renewable Energy and Related Services: Recent Developments", USITC Publication 4421, August.

_________ 2005, "Renewable Energy Services: An Examination of U.S. and Foreign Markets" (Investigation No. 332-462, USITC publication 3805, October.

Vossenaar, Rene, 2013, "The APEC List of Environmental Goods An Analysis of the Outcome & Expected Impact", International Centre for Trade and Sustainable Development (ICTSD), Issue Paper No. 18, June.

World Trade Organization (WTO), undated "Understanding the WTO: The Agreement: Anti-dumping, subsidies, safeguards: contingencies, etc", accessed at https://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm8_e.htm

_________ "Council for Trade in Services—Special Session—Communication from the United States—Initial Offer," TN/S/O/USA, September 4, 2003, cited in USITC, "Renewable Energy and Related Services: Recent Developments", 2013, p. 1-3.

_________, August 2010, "Background Note on Environmental Services: Note by the Secretariat" accessed at https://docs.wto.org/dol2fe/Pages/FE_Search/FE_S_S006.aspx?Query=(%20@Symbol=%20s/c/w/*%20)%20and%20(%20@Title=%20background%20note%20)%20and%20(%20@DocumentDate%20%3E=%202009/01/01%2000:00:00%20)&Language=ENGLISH&Context=FomerScriptedSearch&languageUIChanged=true#.un.org/unsd/cr/downloads/CPCv2.1_complete%28PDF%29_English.pdf

_________ 2010, "Background Note on Environmental Services – Note by the Secretariat". Council for Trade in Services, S/C/W/320.

Würtenberger, L., et al, 2012, "Business Models for Renewable Energy in the Built Environment", IEA – Renewable Energy Technology Deployment, accessed at http://iea-retd.org/wp-content/uploads/2012/04/RE-BIZZ-final-report.pdf