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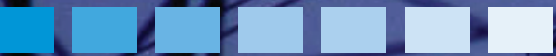
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A case study of the Omani electricity network and readiness for solar energy integration



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Abstract

In this paper a study is made of the electricity network of the Sultanate of Oman. The electricity industry of Oman currently relies on almost 100% fossil fuels – with natural gas (97.5%) and diesel oil (2.5%) being the primary sources of electricity generation. This reliance is expected to change significantly in the coming years. Harnessing solar energy (and wind energy) will help to significantly reduce the country's carbon emission footprint whilst enhancing intra-structural development and ensuring economic stability.

Solar energy density levels in Oman are among the highest in the world. The country receives an extensive daily solar radiation of 5,500-6,000 Wh/m² per day in July and 2,500-3,000 Wh/m² per day in January. With careful planning this energy rich resource may now be harnessed. In this context the regulatory environment in Oman has been gradually trans-forming to minimise the political and administrative barriers for the integration of renewable energies into the Omani electricity and water system networks.

A number of detailed studies have been conducted in scoping potential developments for solar energy resources across Oman. These include (i) a proposal for wide-scale deployment of domestic roof-top PV solar, (ii) feasibility of large-scale generation plant by solar PV and/or Concentrated Solar Power (CSP), and solar thermal as an enhanced oil recovery (EOR) assist. Wind generation is also feasible in a number of regional zones, with one approved development for a large wind farm in the south of the country.

Oman is also connected to its Gulf Cooperation Countries (GCC) neighbouring countries via the Gulf Super Grid. This is a very important development both for the country and for the wider region. With further developments in regional renewable energy generation, prospects for transmission of clean energy between GCC countries and beyond, will emerge. Oman has a dedicated Ministry for Environment and Climate Affairs (MECA). A target of 10% renewable generation by 2020 is already in place. Creation of enhanced renewable governance structures, provision of renewable tariff support, investment planning, and strategic forward planning, are matters for ongoing review.

Keywords

PV Solar, CSP, Roof-top Solar, Solar EOR, Wind Energy, GCC Interconnector, Renewable Pilot Projects.

Glossary

CSP	<i>Concentrated Solar Power</i>
TPES	<i>Total Primary Energy Supply</i>
WMO	<i>World Meteorological Association</i>
MECA	<i>Ministry of Environment and Climate Affairs</i>
EOR	<i>Enhanced Oil Recovery</i>
SEOR	<i>Solar Enhanced Oil Recovery</i>
PDO	<i>Petroleum Development Oman</i>
OCGT	<i>Open Cycle Gas Turbine</i>
CCGT	<i>Combined Cycle Gas Turbine</i>
MIS	<i>Main Interconnected System (Oman)</i>
OPWC	<i>Oman Power and Water Company</i>
GCCIA	<i>Gulf Cooperation Countries Interconnection Authority</i>
IPP	<i>Independent Power Projects</i>
IWP	<i>Independent Water Projects</i>
OPWP	<i>Oman Power and Water Procurement Company</i>
TPGR	<i>Total Power Generation Resources</i>
DPS	<i>Dhofar Power System</i>
DGW	<i>Directorate General of Water</i>
OETC	<i>Oman Electricity Transmission Company</i>
RAECO	<i>Rural Areas Electricity Company of Oman</i>
PAEW	<i>Public Authority of Electricity and Water</i>
IRENA	<i>International Renewable Energy Agency</i>
RRA	<i>Renewable Readiness Assessment</i>
GHI	<i>Global Horizontal Irradiance</i>
DNI	<i>Direct Normal Irradiance</i>
MENA	<i>Middle East and North Africa Region</i>
DNI	<i>Direct Normal Irradiance</i>
GCC	<i>Gulf Cooperation Countries</i>

1. Introduction

1.1 Introduction to Oman

One of the six Gulf Cooperation Countries (GCC), the Sultanate of Oman is a small, stable and prosperous nation of the Middle East. It is located between the Persian Gulf and the Arabian Sea, bordering the United Arab Emirates to the northwest, Saudi Arabia to the west and Yemen to the southwest (see Figure 1). Oman is the third largest country in the Arabian Peninsula, with a land area of 310,000 km². Hosting eleven regional governorates^[i], the principal population and administrative centre is located in Muscat and its northern surrounds, with other principal cities at Sohar, Sur, and Salalah to the south. Oman’s coastline extends 1,700 kilometres from the Strait of Hormuz in the north to the Yemeni border in the southwest.

The country’s central plain is mainly desert (the famed “empty quarter” and home to rich oil reserves), with varied geographic features including the mountainous Hajjar range which covers 15% of the country’s landmass. Experiencing extremely hot temperatures (40°C+) particularly in inland regions for up to eight months of the year, Oman’s largely coastal population benefits from sea breezes and much milder temperatures through the month of October to February^[1]. The combined population of Oman is estimated to be 4.5 million, comprising approximately 2.5 million native Omanis and 2 million expatriates.



Figure 1. Map of Sultanate of Oman and Neighbouring Countries (Magellan Geographix Atlas).

The United Nations Development Report (UNDP) 2010 placed Oman *number one* in the world in the Human Development Index ranking, a formidable recognition which aligns with the steady growth and advancement in health and education, and people and

societal infrastructural development^[6]. Oman also ranked highly as a nation at peace in the 2016 Institute for Economics & Global Peace Index, placed at No: 5 in the Middle East and North African region and 59 in the overall world ranking^[7]. Since 1970 the country has maintained 5-year (short term) and 25 year (longer term) strategic plans. This has enabled Oman to make effective use of its people and resources through various stages of development and opportunity, thus meriting the international recognition it has earned over the past half century.

Oil exploration in Oman commenced in the 1960s, resulting in the first extraction of oil as a natural resource in 1967. With current reserves of approximately 5 million barrels, Oman ranks 25th among world oil-producing nations^[8]. The Total Primary Energy Supply (TPES) of the Sultanate is dependent on natural gas and oil. In 2014 the share of TPES was 80.7% natural gas and 19.3% oil. Oil consumption is mainly confined to the domestic market catering for industrial processes and an expanding vehicle fleet. Oil use in electricity generation is limited to rural off-grid generation plants.

Natural gas is increasingly deployed in electricity generation, desalination and industrial use, including enhanced oil recovery (EOR) in the oil and gas sector. Gas revenue has increasingly been a driving source for the economy. In 2012, for example, natural gas exports accounted for 38% of production^{[2], [3], [4]}. Petroleum Development Oman (PDO) is Oman’s primary exploration and production company, accounting for 70% of crude oil production and almost all of its natural gas production (130 fields with 600 wells). Table 1 provides a list of principal Oman Data Indicators.

Table 1: Oman data indicators	
Oman Key Energy Indicators 2014	
Population ^[ii] (millions) (Feb 2017) Expatriates (2.1m), Native Omanis (2,47m).	4.57
GDP (billion US\$)	67.5
Energy Production (Mtoe)	74.5
Net Imports (Mtoe)	-48.5
Electricity Consumption (TWh)	26
CO2 Emissions (Mt of CO2)	59.9

2. Omani electricity network

Oman’s generation network is powered almost entirely (97.5%) by natural gas, principally using Open Cycle Gas Turbine (OCGT) plants. Combined Cycle Gas Turbines (CCGT) have also been designed for combined electricity production and water desalination. The remaining 2.5% of generation is through diesel engine generators. Owing to its topography, Oman does not have a single interconnected grid. The principal network or “Main Interconnected System” (MIS), located in the north of Oman, services Muscat and six other governorates, totaling upwards to one million customers.

The MIS is owned by the Oman Electricity Network Company (OENC) and comprises a number of power generating facilities, owned and

operated by various companies, in addition to the 400/220/132kV transmission grid and three distribution network operators who act as licensed electricity suppliers. The MIS is interconnected to the power system of Petroleum Development Oman (PDO)^[iii] through a 132kV link at Nizwa, to the Emirate of Abu Dhabi through a 220kV link at Mahadha, and to other member states of the GCC Interconnection Authority (GCCIA). Several of the power generation facilities connected to the MIS produce desalinated water in conjunction with electricity^[iv].

The Oman Power and Water Company (OPWC) is responsible for the purchase of power and water for all Independent Power Projects (IPP) and Independent Water Projects (IWP) in Oman^[v]. OPWC undertakes long-term generation planning and publishes a 7-year statement. Total Power Generation Resources (TPGR) of the MIS system stands at 7800MW (2016/17), with the expectation of reaching 11000MW by 2020^[10]. In respect of water desalination plant, MIS has a current capacity of 900,000 m³/d, with an expected capacity of 1,500,000 m³/d by 2020.

In the south of Oman the Dhofar Power System (DPS) is a much smaller network, serving 92,500 consumers in the Salalah and surrounding outlying areas. The DPS has two generating facilities, a 220kV/132kV transmission grid (owned and operated by OETC), and a distribution network which is owned and operated by the DPC. The Dhofar Power System is interconnected with the power system of Petroleum Development Oman (PDO), via a 132kV link between Thumrait and Harweel^[vi], with a transfer capacity of 150MW.

The Directorate General of Water (DGW) is the principal authority for potable water supplies and distribution in the Governate of Dhofar where a single water desalination plant is the principal source of water. TPGR for the DPS are expected to reach 1600MW in 2017, rising to 2500MW by 2020^{[3], [4], [10]}.

Ad Duqm is located on the eastern coastline of the Al-Wusta region, halfway between the MIS and the DPS. With a small population of 9000 people, the region is entering a rapid growth period owing to the development of a new economic and industrial centre. The region is currently served by a small integrated system owned and operated by the Rural Areas Electricity Company of Oman (RAECO). A 67MW diesel-fuelled power plant supplies the grid, with a second 80MW plant planned for 2018^{[3], [10]}.

The Musandum Governate is an enclave of Oman, located in the northern-most region, separated from the main landmass by the United Arab Emirates, and extending into the Strait of Hormuz. With a population of 39,000, the Musandum Governate is supplied by a number of small diesel generators, with procurement for a further 120 MW^{[4], [10]}.

2.1 GCC Interconnector

As a GCC member state Oman benefits as a contributing partner to the "Power of Six" Gulf Super Grid. The grid was developed in three phases and is managed by the GCC Interconnection Authority (GCCIA). The connector comprises a 400kV transmission network enabling power transfer between the six GCC countries — Saudi Arabia, UAE, Qatar, Bahrain, Kuwait and Oman. Phase I of the project enabled connection between Bahrain, Kuwait, Saudi Arabia and Qatar. Phase II achieved integration of the UAE and Oman

power systems. Phase III linked the networks of Kuwait, Saudi Arabia, Bahrain, Qatar (North Grid) and the United Arab Emirates and Oman (South Grid). This resulted in the construction of six (ABB) 400kV gas insulated substations, a High Voltage Direct Current (HVDC) converter, 830 kilometers of double-circuit 400kV transmission lines, and approximately 50 kilometers of land and submarine cable. The HVDC link enables power flow between the Saudi Arabia grid, which operates at 60Hz, and the other five states, which operate at 50Hz^[11].

2.2 Tariff Subsidies

Electricity provision in Oman is highly subsidized, and is equally priced to end-users in all locations throughout the Sultanate. Financial subsidies by the government to licensed suppliers ensures prices to consumers are kept well below the generation, transmission and distribution costs (direct financial subsidies). Indirect subsidies to electricity producers have also ensured low prices on natural gas and diesel fuel. In 2012 the average subsidy was 42% and upwards to 80% in rural jurisdictions. It is proposed that the financial subsidy to electricity in rural areas is higher than the projected generation costs of solar PV. In addition to subsidies to the domestic population, low gas prices have been a major driving force towards economic growth and diversification in the Sultanate^{[3], [4]}.

3. Overview of renewable energy feasibility studies

3.1 Solar feasibility studies

Indicative levels of solar radiation in Oman for the months of January and July are shown in Figure 2. Levels are among the highest in the world. Several studies have been carried out on behalf of the Oman Public Authority for Electricity and Water (PAEW) in determining the country's suitability and readiness for diversification to renewable energy generation^[5]. A study review of solar technologies, including concentrated solar thermal power technologies (parabolic trough, power trough, and linear Fresnel reflector), photovoltaic technologies (monocrystalline and polycrystalline cells, thin-film modules, inverters, mounting structures, axial tracking), and concentrating photovoltaics (similar to PV but utilising optical concentrators to concentrate sunlight from a broad collection area onto a small area of active semiconductor photovoltaic cell material) was completed in 2010^[12].

Examples of large-scale projects based on related technologies include installations in the US, Spain, Portugal, Germany, South Korea, Greece, China and India. For CSP plant, thermal energy storage and natural gas co-firing mechanisms are considered. Worley Parsons recommended co-firing over thermal energy storage for CSP plant installations in Oman. It was further recommended that CSP through CSP tower and direct steam generation and flat plate PV, be considered depending upon site conditions and suitability. Design capacity ranges of 80MW to 100MW are recommended for stand-alone CSP plant. For flat plate photovoltaic plant, a capacity limit of 50MW, has been recommended.

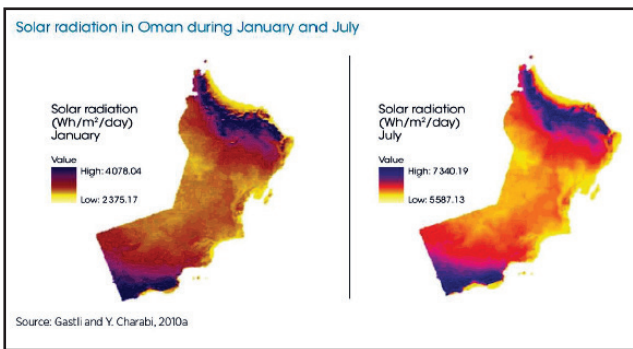


Figure 2. Oman: Solar Radiation January and July (retrieved from [3]).

3.2 Renewable Readiness Assessment Study

A Renewable Readiness Assessment (RRA) completed by the International Renewable Energy Agency (IRENA) has further investigated the case for diversification to solar and wind energy in the Sultanate^[3]. In determining suitability for solar generation, average daily sunshine duration and solar radiation data has been amassed for different locations in Oman, deemed among the best in the world. Locations of highest solar radiation include Marmul, Fahud, Sohar and Qairoon Hairiti.

Most other areas have similarly-good radiation levels except for Salalah and Sur, which have significantly lower insolation owing to the summer Khareef (rainy season) in Salalah and on account of frequent fog in the Sur region^[viii]. Mappings of Global Horizontal Irradiance (GHI: total amount of shortwave radiation received from above by a surface horizontal to the ground), and Direct Normal Irradiance (DNI: radiation approaching in a straight line from the direction of the sun from its current position in the sky) are shown in Figure 2.

From a study of 23 locations identified as suitable for large solar projects, four have been highlighted to have significant potential. These include Adam, Managh, Al Khaboura and Ibri. Land evaluations have been completed and tenders are being prepared. Future projects at Adam and Managh may be large-scale programs in the 100MW-200MW range.

3.3 Roof-top Solar Study

A technical study on the potential for rooftop solar PV in Oman forms the basis for evaluation of the wide-scale utilisation of domestic solar generation with grid connectivity^[13]. The study estimates that there may be upwards to 25 km² of roof area in the Sultanate with technical potential of 1.4GWp (gigawatt peak) for installed roof-top PV power. With an average irradiation resource of 2240 kWh/m², the average PV system yield was estimated to be 1750 kWh/kWp (kilowatt peak). With an expected variation in PV system yield throughout the country and accounting for all typical module orientations of $\pm 10\%$, this offers an attractive proposition in forward energy planning. If fully exploitable, in excess of 2TWh of annual electricity production from domestic PV systems, could be realisable.

In order to effect implementation, two PV system cost scenarios were articulated. Based on previous experience in Germany, a commencement system price of 3300 \$/kWp was proposed. Following a period of five years of market development, a system

price of 1900 \$/kWp, may attain. This analysis catered for a Feed-in Tariff (FIT) of 17.5 cUS\$/KWh for small residential PV systems (of 10 to 15 kWp). The study considers roof-top size of 100m² to 200m², with PV sizes ranging from 5kWp to 11kWp, which is equivalent to 30 to 70 standard crystalline silicon and one (or two) inverters. In terms of PV modules for grid access, a regulatory framework permits a household to produce electricity and to sell it, with appropriate FIT in place. Binding rules on grid access will be required in order to effect implementation by the distribution system operators. In order to implement a pilot phase an appropriately trained team will be required.

PV Panel Dimensions

Roof-top size of 100 m² to 200 m², with PV sizes ranging from 5 kWp to 11 kWp which is equivalent to 30 to 70 standard crystalline silicon and one (or two) inverters

Feed-in Tariff (FIT) of 17.5 cUS\$/KWh for small residential PV systems (of 10 to 15 kWp)

4. Examples of renewable projects in Oman

4.1 Solar enhanced oil recovery

The key factor determining an area's suitability for concentrated solar power production is the Direct Normal Irradiance (DNI) value. In Oman the GAC estimate that this amounts to 2200kWh per m² per year, which could yield 19404TWh of electricity per year.

In addition to the application of electricity generation, solar energy has become an assist technology with other industrial applications. One such application is that of thermal Enhanced Oil Recovery (EOR), a process wherein steam (created by solar concentration) is injected into a reservoir and, in so doing, enhances the flow and oil production. Petroleum Development Oman (PDO) – in partnership with the renewable energy design company GlassPoint – has developed an enclosed trough technology housing thin curved mirrors inside a greenhouse. The mirrors track the sun throughout the day, focusing heat on pipes containing oilfield water. The concentrated sunlight boils the water to generate steam, which is then injected into the oil reservoir to enhance mobility. Steam injection increases the rate of oil production and can extend the lifetime of an oil field. The greenhouse protects the mirrors from high winds and blowing sand and dust. It has an automated washing machine to maintain optimal performance even in harsh oilfield desert conditions. By bringing the solar collectors indoors, the company has achieved a number of capital and operating cost reductions compared to exposed



Figure 4a. Thermal Enhanced Oil Recovery (EOR) PDO-GlassPoint (retrieved from [14]).

solar thermal designs. As a result, the solar steam generators can produce steam at costs that are competitive to natural gas in many oil-producing regions^[14]. The project utilises a 7MW solar array to produce 11 tons/hour of high pressure steam which will be used to extract 33,000 barrels of oil, in addition to providing reserve plant heating.

Features

- Enclosed trough technology housing thin curved mirrors inside a greenhouse
- Automated greenhouse spray cleansing system⁽¹⁾
- Mirrors track sun throughout the day, focusing heat on oilfield water pipes⁽²⁾
- The steam generated is injected into the oil reservoir to enhance mobility
- 7 MW solar array produces 11 tons/hour of high pressure steam

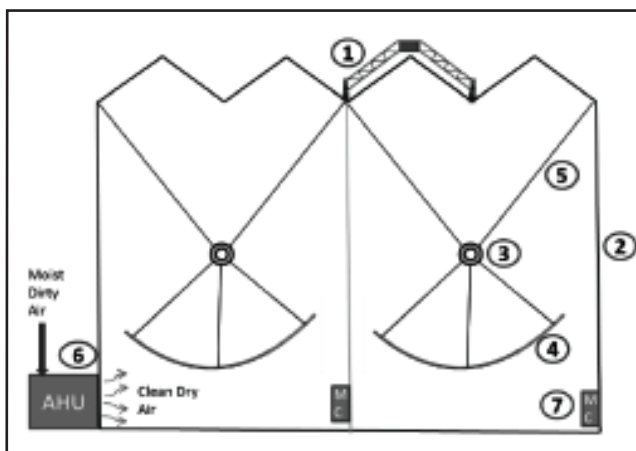


Figure 4b. System schematic – solar tracking curved mirrors enclosed in greenhouse.

4.2 Renewable Energy Pilot Projects in Oman

The Rural Areas Electricity Company of Oman (RAECO) accepted the remit for a number of renewable projects, including a 4700kW wind project at Masirah Island, and at Sharqia and Al Khariat in the Dhofar

region. Other planned developments include 2000kW of solar projects in the Dhofar and Wusta regions. Other small-scale projects approved by the Authority for Electricity Regulation (AER) include a 100kW solar project at Hiji, a 290kW project at Al Mazyonah, 28kW solar project at Al Mathfa incorporating battery storage capability, a 500kW wind project at Masirah Island, and 4200kW wind projects at Saih Al Khairat, Wilyiat and Thumrait^{[3], [10], [18]}.

4.3 Dhofar Wind Energy Farm

In tandem with solar energy studies, a number of wind energy studies have been conducted to determine the wind energy resource potential across the Sultanate. Studies conducted confirm that coastal and southern regions of Oman are promising areas for wind energy generation, with typical average wind speeds of 5m/s and 2500 peak operational hours per year recorded^{[14], [19]} (see Figure 5). Abu Dhabi's renewable energy company, Masdar, signed a joint development agreement with RAECO in 2014 to design and build a 50MW wind farm, with location at Harweel in the Dhofar Governate.

With contract cost in the region of \$125M, this will be the first large-scale wind farm in the GCC. The project is estimated to generate enough clean electricity to power 16,000 homes and mitigate 110,000 tons of CO₂ per year^[14]. It will be capable of delivering 50% of the Dhofar region electricity needs during the winter months. The development will comprise of 15 to 25 turbines, with energy ratings of 3.0 to 3.2MW, and a height of 120m.

5. Salient opportunities for national and regional renewable energy deployment

A review by the Oxford Institute for Energy Studies subscribes to the growing belief that renewable energy, in particular wind and solar energy, can offer the MENA region a viable alternative to fossil

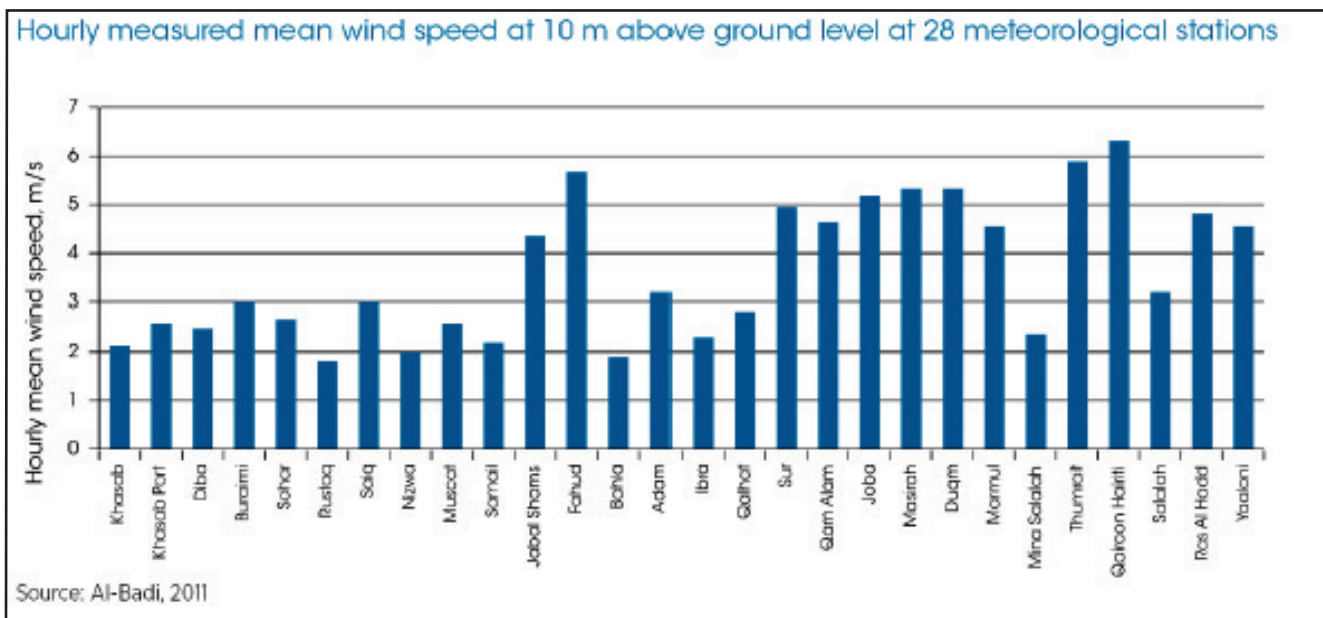


Figure 5. Oman, Location Wind Speed Recordings (retrieved from [3]).

fuels in power generation^[15]. Given the available landmass area and insolation richness, the opportunity now exists to make serious inroads in moving from crude oil and natural gas to renewable energy technologies. A cost-competitive environment for enhancement of renewables has now been presented. Although the crude oil market has stabilised at approximately \$55 per barrel, it is not likely that prices will return to their earlier lofty levels. Oil producing countries, not least Saudi Arabia, are suffering the consequence with national income reductions of up to 50% of those of recent years. There is a requirement for structural reform of domestic energy market pricing. The opportunity is now available to address this requirement.

The important building blocks have already been taken in the MENA region, in particular as evidenced by the success of K. A. Care (King Abdullah City for Atomic and Renewable Energy), and Masdar (Abu Dhabi's renewable energy city). K. A. Care is a state agency vested with the authority to initiate renewable energy deployment and create new institutions as required for policy implementation. Masdar is also a sustainable development model, creating a high-tech city combining education and R&D, and underpinned by funding and construction of a series of solar plants in Abu Dhabi and an active renewable investment policy in various parts of the world^[3].

Cross-regional electricity trade may yet prove one of the more effective ways to make renewable energy investments profitable for a growing number of investors in the MENA region. The GCC interconnector opens up the possibilities for smaller countries, such as Oman, to develop solar and wind energy projects which will change the current status of fossil-fuel dominance in the nation's energy mix, while also permitting clean energy transfer to MENA and indeed further afield. Two of the MENA region's largest solar plant projects, the EU-sponsored Mediterranean Solar Plant (MSP) and the German-US-MENA Desertec large-scale solar project, have been created in line with policy and incentive to be able to deliver profitably on an international footing^{[15], [16]}.

Prior to the steps needed towards renewable energy exchange, and potentially net export, the next five years will be crucial to Oman in determining the degree of diversification to solar and wind energy generation the country is likely to embrace. In respect of roof-top solar, the Fraunhofer study has determined the potential for a combined installation totalling 1400MW, which would constitute a sizable contribution to the Omani domestic generation requirements, not least in meeting domestic and small enterprise air-conditioning loads.

This presents a challenging, and perhaps overtly optimistic, end goal. Nevertheless, if appropriate steps are taken and policies determined, a significant achievement in realising localised PV domestic requirements will represent a first for Oman in the MENA region. A detailed outline plan envisages employment opportunities ranging from 1,000 to 4,000 per annum associated with the project, including design and preparation, installation phases, and on-going post-installation maintenance.

The Government of Oman is considering further developments of up to 200MW PV/CSP plant. It is envisaged that a cost-reflective tariff under long-term power purchase agreements may be used rather than by feed-in tariffs. It is hoped that such projects will receive

Public Authority for Electricity and Water approval, thus setting a benchmark for greater introduction of solar power to the nation's energy mix. Three or four such projects, combined with further wind farm developments over the coming five to ten years, would be of significant import to Oman, both in terms of diversification to clean energy and a reduction of the emission footprint, and in marking Oman's future intent as a lead country in renewal energy in the MENA region and beyond.

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- [i] Governates of Oman include Muscat, Dhofar, Musandum, Al Sharqiyah South, Al Sharqiyah North, Al Wusta, Al Buraimi, Al Batinah South, Al Batinah North, Al Dhahirah, and al Dakhiliyah.
- [ii] National Center for Statistics and Information, Sultanate of Oman. www.ncsi.gov.om Population Clock.
- [iii] PDO, the main oil and gas Exploration Company in Oman, owns and operates a dedicated power system, of 12 GW capacity. The network is interconnected to the MIS and Dhofar power network systems, forming an important link in the country's wider electricity network.
- [iv] Oman is dependent on desalination for its water supplies. Sea water is desalinated in seven large plants. Five plants are combined power and desalination, the remaining two are standalone water producing plants. Water demand is growing at approximately 8% per year. In the combined CCGT plants, heat is provided to the water production process. Co-production is energy efficient, realizing 20% improved efficiency over standalone electricity and plant provision [9].
- [v] GCC reliance on IPPs is set to increase. Oman is seen as having taken a lead GCC efforts to unbundle the power sector by privatizing most of its generating assets, and is also considering privatizing transmission and distribution networks. APICORP Energy Research. Arab Petroleum Investments Corporation. September 2016. "GCC Power Markets: reliance on IPPs set to grow". energy.research@eircorp-arabis.com
- [vi] Harweel is the location of Oman's first major wind farm; 50 MW farm expected completion 2017
- [vii] A Renewable Readiness Assessment (RRA) of the Sultanate of Oman has been undertaken by the international Renewable Energy Agency (IRENA), published in November 2014. In the report Foreword Mohammed Abdullah Al-Mahrouqi, Chairman of the Public Authority of Electricity and Water, informs that "the demand for energy in the Sultanate is increasing rapidly, due to a combination of rising population and strong economic growth; with annual electricity demand growth at 8-10%, reflecting the rapid expansion of industrial areas as the economy diversifies away from the oil and gas sectors". Further, "the Government of Oman has started to examine the possible use of renewable natural resources for the production of electricity, with a view to diversifying the energy base of the Omani economy".

Note: This paper is published in association with a study entitled "Steps towards the decarbonisation of the Omani electricity grid", presented at Cigre Symposium Dublin, May/June 2017. Authors: Eugene Coyle, Jonathan Blackledge, Abid Ali Khan, Muhammad Arid Ashraf.