Consultation Paper: 03/2017

هيئة تنظيم الكهرباء - عمان

AUTHORITY FOR ELECTRICITY REGULATION, OMAN

Public Consultation on Residential PV in Oman

May 2017

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Glossary

BST	Bulk Supply Tariff
CCGT	Combined Cycle Gas Turbine
CO_2	Carbon Dioxide
DPC	Dhofar Power Company S.A.O.C.
FiT	Feed in Tariff, a scheme under which electricity produced by a PV system and injected into the grid is paid a predefined price that may be guaranteed for a fixed period and may be subject to indexation.
GHi	Global Horizontal Irradiance, also known as Global Solar Radiation, is the total amount of direct and diffuse solar radiation calculated as follows: GHI = DNI. Cos (Z) + DHI Where: GHI = Global Horizontal Irradiance DNI = Direct Normal Irradiance DHI = Diffuse Horizontal Irradiance (Z) = Zenith Angle Source: http://www.omanpwp.com/PDF/Solar%20Data%2Webpack%20v8%20clean.pdf
I(W)PP	Independent (Water) and Power Projects
Majan	Majan Electricity Company S.A.O.C.
Mazoon	Mazoon Electricity Company S.A.O.C.
MIS	Main Interconnected System
Muscat	Muscat Electricity Distribution Company S.A.O.C.
OCGT	Open Cycle Gas Turbine
OPWP	Oman Power and Water Procurement Company S.A.O.C.
PV	Photovoltaic
RAEC	Rural Areas Electricity Company S.A.O.C.
Residential Customer	A Customer supplied with electricity subject to the Residential Permitted Tariff
Residential Permitted Tariff	The Tariff approved by the Council of Ministers that licensed electricity suppliers are required to charge for electricity supplied to Residential Customers
Residential PV	A system comprising Photovoltaic (PV) panels and related equipment installed at the premises of a Residential Customer
SRTP	Social Rate of Time Preference
The Authority	The Authority for Electricity Regulation, Oman

Section 1: Introduction & Purpose of Consultation

1. The Authority wishes to Consult with Customers, Industry Participants, stakeholders and interested persons on an initiative to accelerate the installation of solar PV systems at residential premises in Oman (Residential PV). This paper explains why the Authority believes a Residential PV initiative should be implemented, the potential benefits, and how the proposal might be shaped and structured to help Oman make better and more efficient use of an available and valuable renewable resource.

2. The Authority invites views and comments on all aspects of the proposed Residential PV initiative and the supporting analysis that suggests an initiative to install PV systems of between 2kWp to 4kWp at 10% to 30% of Residential premises would provide positive net benefits to Customers, the electricity sector, and the Oman government.

Consultation Timeline

3. The Authority invites responses to the Consultation by 28 May 2016. Please direct responses to:

   Qais bin Saud Al Zakwani

   Executive Director & Member

   Authority for Electricity Regulation

   P.O. Box 954,

   PC 133 Al Khuwair

   Sultanate of Oman

   Email: consultations@aer-oman.org

4. The Authority will carefully consider all responses and may undertake further analysis in the light of comments received.

5. The Consultation Paper is structured as follows:

   (i) Section 1 outlines the context in which the Consultation takes place;

   (ii) Section 2 summarises international trends in PV deployment and the findings of a review of relevant literature undertaken to assess academic thinking on solar resource valuation and experience of residential PV programmes in other jurisdictions;

   (iii) Section 3 discusses the limited incentive properties of the Residential Permitted Tariff and presents analysis results;

   (iv) Section 4 discusses international trends in Residential PV system costs;

   (v) Section 5 discusses possible support mechanisms and outlines the Authority's role in progressing the initiative; and

   (vi) Section 6 summarises the analysis conclusions and describes the Residential PV initiative proposed by the Authority.

6. References for articles in the literature review and various reports referred to in the consultation paper are provided in Annex A. Annex B - available as a separate document – describes the analysis methodology, key assumptions, data sources, and modelling techniques.

Summary of Residential PV Initiative

7. The Residential PV initiative proposed by the Authority is as follows:

i. The phased installation of 2kWp – 4kWp PV systems at the premises of around 10% to 30% of residential customers, 58,078 (Group 2) to 181,673 (Group 7) accounts respectively;

ii. Funding for an initial phase of the initiative would comprise (i) an advance of future gas saving benefits and subsidy reductions and (ii) customer contributions based on a multiple of either (a) annual bills, or (b) the present value of five-years of anticipated bill savings. Payback periods for customer contributions would be between 3 to 5 years after which customers would continue to receive the full benefit of bill reductions;

iii. The Authority will supervise the installation of an initial tranche of Residential PV systems that, once installed and demonstrating satisfactory performance, would be offered as an investment opportunity to investment funds who would recover their investment, and an agreed competitive rate of return, from payment streams aligned to PV system output reflecting the monetised economic benefits described in this paper. The Authority would utilise funds from the sale of the initial tranche of PV systems to finance a further tranche of Residential PV, and so on until the initiative target is achieved. Work is ongoing to clarify and finalise details of the transactions framework;

iv. Our analysis suggests a Residential PV initiative could deliver the following benefits:

   a. Gas savings over 25 years of between **2 billion Sm^3** (Group 2 accounts, 3kWp systems) and **6 billion Sm^3** (Group 7 accounts, 3kWp systems);

   b. The present value of gas savings over 25-years is between **RO 161 million** (Group 2 accounts, 3kWp systems) and **RO 505 million** (Group 7 accounts, 3kWp systems)[1];

   c. CO_2 emission reductions over 25-years of between **3.2 million tons** (Group 2 accounts, 3kWp systems) and **10 million tons** (Group 7 accounts, 3kWp systems);

   d. Average reductions in annual customer bills of between **42%** (Group 2 accounts, 3kWp systems) and **34%** (Group 7 accounts, 3kWp systems); and

   e. Some reduction in system peak demand in summer months, and lower system demand in all months during hours when solar irradiation is available. Any reduction in system peak demand would provide additional benefits in the form of lower investment in electricity networks and production capacity;

v. The reported costs of small scale Residential PV systems are between 1US$ per W (China) and 3US$ per W (USA). Our estimates of 25-year gas saving benefits from 3kWp systems equate to US$2,777 or RO 7,200 per account, which is within the range of reported PV system costs and suggests that even without incorporating environmental benefits or savings in network and production capacity investment, the benefits of a Residential PV initiative may exceed its costs; and

[1] See Appendix 2 for results and sensitivity analysis for Group 2, Group 7 and Group 10 benefits.

vi. The Authority understands some residential customers may wish to install PV systems for environmental and other reasons. To support this, the Authority is preparing to implement the following scheme in addition to the initiative outlined above:

a. Customer funded PV systems installed at residential premises will, subject to compliance with certain criteria, be eligible for remuneration at the relevant BST for PV production exported to the grid;

b. To qualify for the scheme, customers must demonstrate that PV systems comply with new renewable standards and connection conditions approved by the Authority;

c. PV systems participating in the scheme must incorporate approved metering systems to meter hourly PV export to the grid to facilitate settlement with time based elements of the BST; and

d. The scheme will be subject to capacity limits and implemented in phases to ensure the deployment of residential PV systems does not compromise the operation and performance of distribution systems to which they connect.

8. The Authority invites comments and observations on these proposals.

Section 2: Background & Context of Consultation

10. In May 2008, the Authority published an assessment commissioned from international consultants of Oman's renewable energy potential with recommendations on how renewable resources might be efficiently and effectively utilised[2]. The study found solar energy density in Oman to be amongst the highest in the world.

11. The Authority regrets that since publication of the 2008 study, the electricity sector has made only limited progress to utilise Oman's abundant solar resources. There have been some welcome developments: numerous small-scale PV systems now operate throughout the Sultanate and RAEC has successfully implemented one of the Authority's pilot projects comprising a 20-year PPA based privately funded 300kW solar facility in Al Mayzouna.

12. The Authority must also acknowledge the partnership of GlassPoint and Petroleum Development Oman for successfully piloting the Middle East's first solar enhanced oil recovery project.

13. Following publication of the Authority's renewable study the Public Authority for Electricity and Water contracted the Meteorological Office Oman to supervise, monitor and maintain two meteorological stations in Adam and Manah. The two monitoring stations record solar radiation and other data to support the future development of large scale solar facilities. The OPWP is now responsible for supervising the monitoring stations the data from which has been invaluable to the analysis in this paper.

14. Welcome though these developments are the fact remains that in 2016 all grid supplied electricity in Oman was sourced from fossil fuel generation: 96% natural gas and 4% diesel.

15. Limited progress made to utilise Oman's abundant solar resources has increased the electricity sector's reliance on fossil fuels, natural gas in-particular. There is some uncertainty about whether sufficient Oman gas will be available for new I(W)PP needed to meet forecast growth in electricity and water demand. Moreover, large commercial and industrial companies require significant quantities of gas for strategic projects placing further pressure on one of Oman's most valuable natural resources.

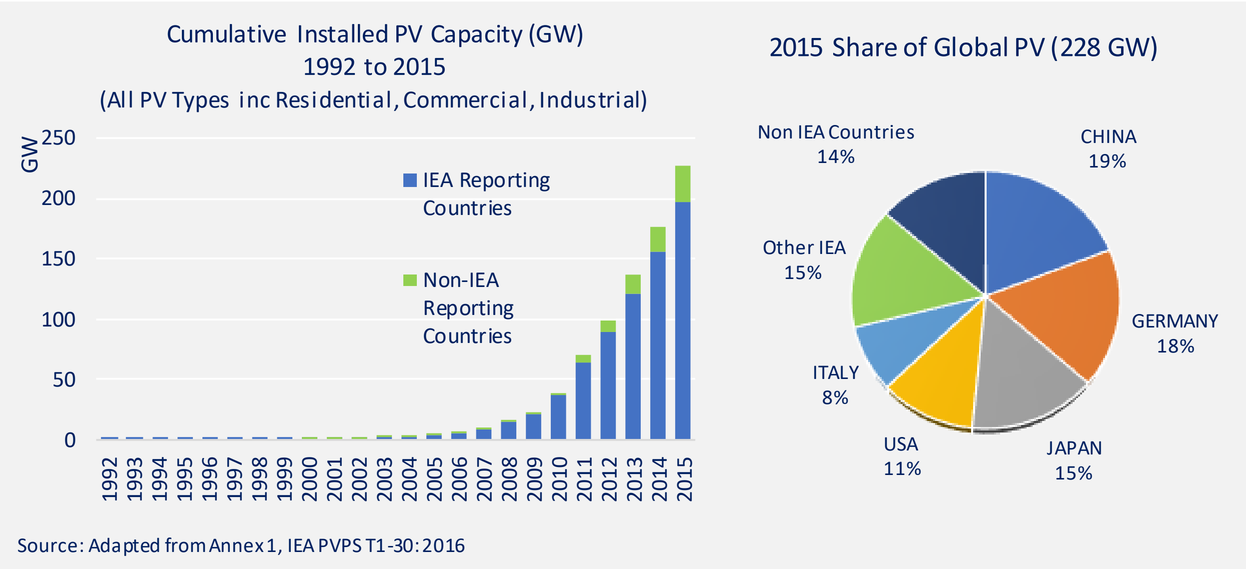
16. The Authority believes a Residential PV initiative, if carefully implemented on a sufficient scale, could help alleviate gas supply constraints and diversify the fuel mix.

[2] Study on Renewable Energy in Oman, Final Report, May 2008.

International Trends in PV Deployment

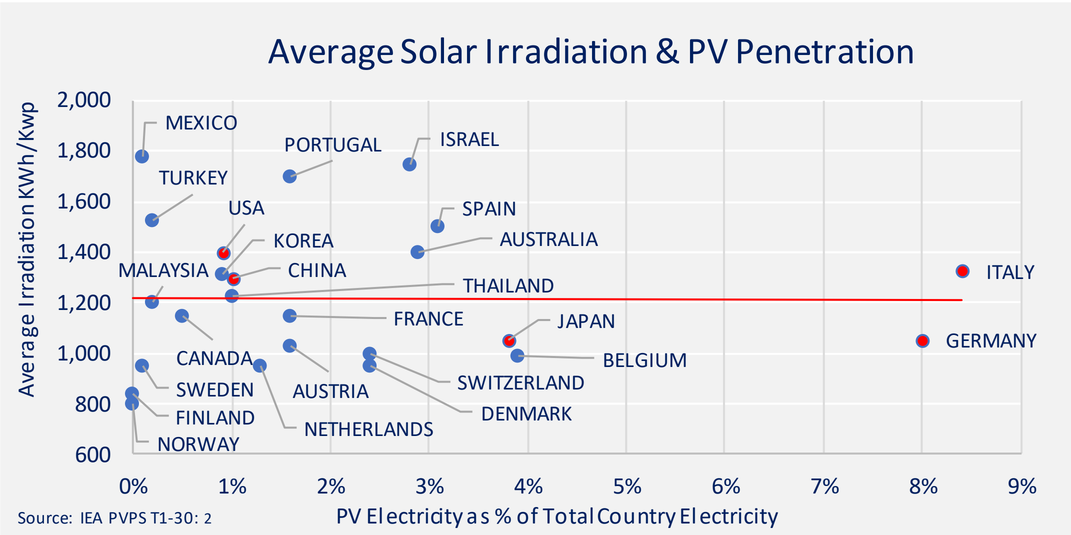
17. The global deployment of PV technologies has accelerated in recent years: PV capacity increased from 4.2GW in 2005 to 228GW in 2015, with 51GW of capacity installed in 2015 alone. However, PV is heavily concentrated in 5 countries that in 2015 accounted for 71% of global PV capacity, see Figure 1.

Figure 1: Cumulative Installation of PV Globally – 1992 to 2015



18. Notwithstanding the accelerating deployment, PV penetration (PV share of total generation) remains low. Figure 2 shows that in 2015 PV in Italy and Germany accounted for around 8% of total electricity, but in all other countries PV penetration was less than 4%.

Figure 2: Average Solar Irradiation & PV Penetration - 2015



19. There appears to be no correlation between a county's solar radiation and PV penetration: the slope of the fitted red line in Figure 2 is zero. PV penetration is evenly distributed across countries irrespective of solar radiation which may reflect the wide range of policies and support mechanisms used to promote PV in different countries.

20. The Residential PV initiative proposed by the Authority, in the case of 10% of residential accounts, would constitute PV penetration of 1%.

Literature Review

21. The Authority reviewed relevant literature to assess current academic thinking on solar resource valuation and to benefit from experience of residential PV initiatives in other jurisdictions[3]. Several valuable points emerged from our review:

i. **Consider multiple perspectives**: while private and public valuations of renewable energy benefits differ, economists stress the importance of considering the different incentives of market participants along 'a continuum of perspectives'[4];

ii. **Levelized cost methodology may undervalue Solar**: levelized costs are a useful way of comparing the costs of different generating technologies, as they reflect "*the constant (in real terms) price for power that would equate the net present value of revenue from the plant's output* with *the net present value of the cost of production*."[5] While the levelized cost methodology has merit, it may fail to take account of certain renewable energy characteristics and may therefore undervalue renewable resources:

> "*Residential solar does offer greater value than suggested by its high levelized cost—because it produces disproportionately at times of high demand, reduces transmission investment, and avoids the small percentage of power that is dissipated as heat when it is sent through the transmission and distribution lines from a distant generator*."[6]

iii. **'Second Best' support mechanisms**: if the motivation for promoting electricity generation from renewable energy is to reduce the unpriced pollution of burning fossil fuels, economists believe the best public policy response is to tax fuel related emissions directly. In the absence of this 'first best' solution, many countries deploy 'second best' solutions that are hoped will do more good than harm.[7] Supporters of feed-in tariffs (FiTs) believe they are the most cost effective way of supporting renewable energy. Others disagree and point to windfall profits made by some investors under FiT schemes and resulting implications for government deficits (as in Spain) and customer tariffs (as in Germany). The renewable energy transition in Germany is funded by a levy on all electricity consumers[8]. Policy makers have been advised to focus on reducing upfront investment costs (to reduce payback periods) rather than provide generation-based remuneration[9]. There appears to be no clear consensus about the best form of solar support mechanism, but general agreement that the optimal design of renewable support mechanisms should reflect the solar irradiance profile, public policy objectives, resource endowments and market characteristics of the implementing country.[10]

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[3] See Annex A for references.
[4] Borenstein (2012)
[5] Borenstein (2008a)
[6] Borenstein (2012)
[7] Borenstein (2012)
[8] Fraunhofer ISI (2017)
[9] University College Dublin (2016)
[10] University College Dublin (2016)

iv. **Time horizons**: assessments of solar electricity costs and benefits are sensitive to the valuation time horizon. In the short term, PV cost effectiveness will reflect the cost of energy (including losses) displaced by incremental increases in solar electricity and associated emissions reductions. In the medium term, solar electricity may displace existing, or reduce the need for some new, conventional generating capacity. But higher solar penetration may increase grid integration costs and the cost of back up generation required to manage intermittency.[11]

v. **Benefits and dis-benefits of PV self-supply**: in some countries customers who install Residential PV benefit from lower electricity bills and receive payments for excess electricity they export to the grid. This may benefit some customers but not others who may face higher network costs[12]. Electricity networks are largely fixed-cost businesses. If the volume of distributed electricity falls (due to Residential PV self-supply), per-kWh charges for network using customers will increase. Policy responses to criticisms about the unfairness of these arrangements has seen the introduction of network charges for owners of Residential PV in some countries, and in others a determination that electricity fed into the grid should not be remunerated.[13] Retrospective changes to renewable support mechanisms are claimed to be a significant barrier to renewable energy – highlighting the importance of policy stability.

vi. **Do not underestimate challenges**: one of the most important points to emerge from our review is that implementing renewable energy initiatives, including Residential PV, can be complex and challenging. While there is clear and growing evidence that Residential PV programmes can produce real economic and environmental benefits, if not carefully designed, implemented and managed the potential benefits may be eroded by higher costs, poor performance, low take up, or other unintended consequences.

[11] Baker et al (2013)
[12] EU Fraunhofer ISI (2016)
[13] EU Fraunhofer ISI (2016)

Section 3: Assessing the Potential Benefits of a Residential PV Initiative

22. Informed by the literature review, the Authority developed a modelling framework to assess the potential benefits of a Residential PV initiative. The analysis methodology is described more fully in Annex B.

Analysis Perspectives

23. The benefits of a Residential PV initiative in Oman are assessed from two perspectives:

    i. First, from the **perspective of the national economy** to assess whether a Residential PV initiative would offer positive net benefits irrespective of the beneficiaries; and

    ii. Second, from the **perspective of Residential customers** at whose premises PV systems would need to be installed if benefits are to be realised.

24. The Authority sought to ensure the analysis utilised Oman data to the maximum possible extent including actual residential electricity consumption, electricity system demand profiles, measured solar irradiance in Oman, and the volume, cost and emissions content of natural gas used to generate electricity in Oman.

25. Simulation techniques were used to capture the uncertainty of hourly solar irradiance and the variability of seven categories of PV system losses (see Annex B for details and a full description of the analysis methodology).

Analysis Questions

26. Modelling was undertaken to provide answers to the following analysis questions:

    i. How much electricity could Residential PV systems ranging in size from 1kWp, 2kWp, 3kWp, 4kWp and 5kWp produce given measured solar irradiance in Oman?

    ii. What would be the distribution and monthly profile of Residential PV in terms of (a) self-supply (b) export of surplus kWh to a distribution system?

    iii. How would Residential PV affect the hourly profile of system demand, in each month at times of maximum and minimum demand?

    iv. What would be the likely magnitude of fuel savings (natural gas) in terms of volume (Sm^3) and economic cost (Rial Omani)?

    v. By how much could Residential PV reduce natural gas related CO_2 emissions in Oman?

    vi. How would Residential PV affect tariff revenues and Customer electricity bills?

    vii. How would Residential PV affect distribution companies' ability to recover network costs?

Keys Consideration: Residential Electricity Tariff

27. The present level and structure of the Residential Tariff is a key consideration when contemplating the design of an appropriate Residential PV support mechanism:

i. Electricity supply to residential customers in Oman is heavily subsidised. Without significant increases in tariffs, residential customers have little incentive to install PV systems from which they are unlikely to derive positive economic benefits; and

ii. The financial burden of funding electricity subsidy falls to the government – both in financial terms and related opportunity costs. While the government will benefit most from a Residential PV initiative, the government may be unwilling to support any initiative that would further increase electricity subsidy above present levels.

28. Figure 3 explains how we expect electricity consumers and the government to view the costs and benefits of a Residential PV initiative given the present tariff level and structure.

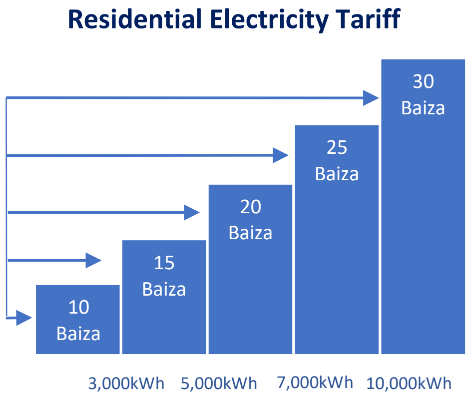
PV from Customers Perspective

A: Each PV kWh will be valued in terms of:
- Electricity bill savings: but at present most Customers pay 10Bz per kWh; and
- Payments, if any, for PV kWh exported to a distribution system;

B: Customers consuming more than 3,000kWh p/m will always value the first 3,000kWh at 10Bz/kWh, i.e. RO 30;

C: Customers may value the security benefits of PV that can mitigate the effects of supply interruptions due to system faults;

D: As the Residential Tariff does not reflect the wider (external) costs and benefits PV – such considerations will not influence decisions to install PV systems.



PV from National Economy Perspective

A: Every kWh of Residential PV reduces:
- Grid supplied kWh (and losses);
- I(W)PP gas requirements;
- Fossil fuel emissions (if displaced gas is exported or gas imports reduced);

B: Residential PV that coincides with system peak demands may lower transmission/distribution and generating capacity investment; and

C: In the long term, Residential PV may reduce the economic cost of electricity supply and associated subsidy requirements.

Figure 3: Two Perspectives of the Costs and Benefits of Residential PV

29. Residential customers benefit directly from a heavily subsidised tariff and indirectly from subsidised natural gas used to generate electricity. If the wider economic and environmental benefits of Residential PV are not acknowledged there is a risk that the government may view the cost of a Residential PV initiative as additional subsidy.

30. Under the existing Residential Tariff customers have little incentive to install PV systems most electricity falls within the lowest band of the residential tariff for which customers pay 10 baiza per kWh – well below the economic cost of supply and below the cost of electricity from a Residential PV system.

31. Without intervention, the Authority believes the benefits of gas savings and emission reductions will not materialise to the detriment of the national economy.

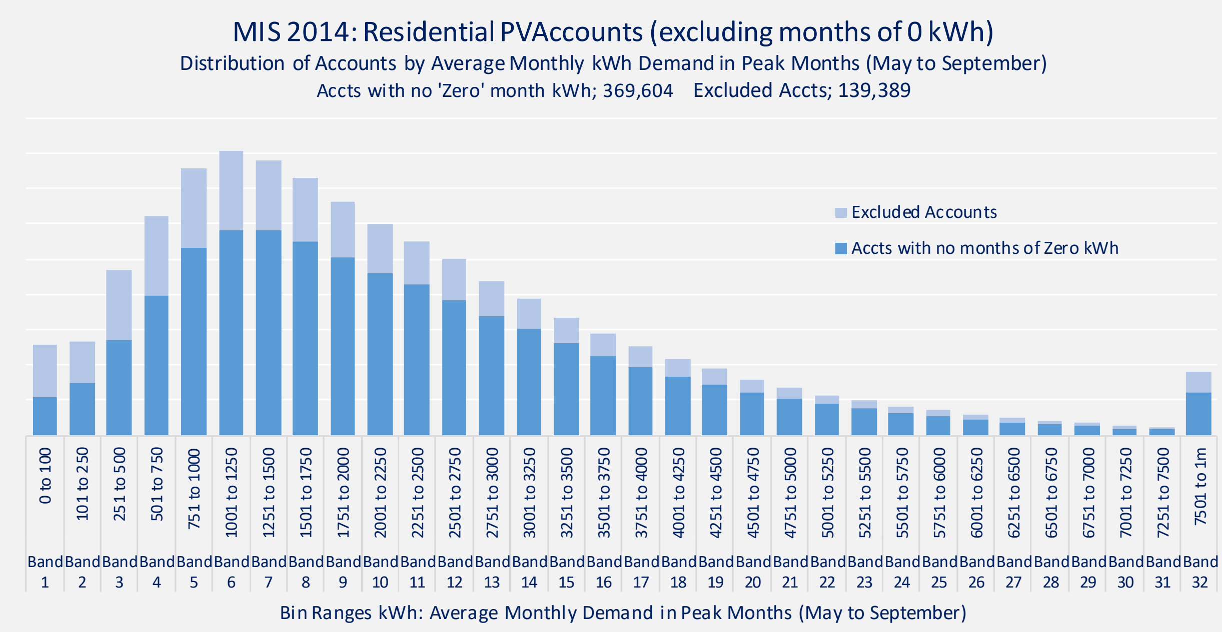
32. The Residential Tariff constitutes a significant 'market failure' that the Authority has sought to address when designing the proposed Residential PV initiative.

33. The following sections describe the modelling analysis and presents estimates of the potential benefits of a Residential PV initiative.

Analysis Results: MIS Monthly Self Supply & Export

34. A key focus of the analysis was how residential PV systems would interact with residential electricity consumption in Oman. Figure 4 presents the distribution of MIS Residential Accounts in bands that reflect average kWh consumption in May to September 2014 (BST peak months) – see Annex A for further details. Accounts with zero consumption were excluded leaving a sample of 369,604 MIS Residential Accounts.

Figure 4: MIS 2014 Residential Customer Account Database



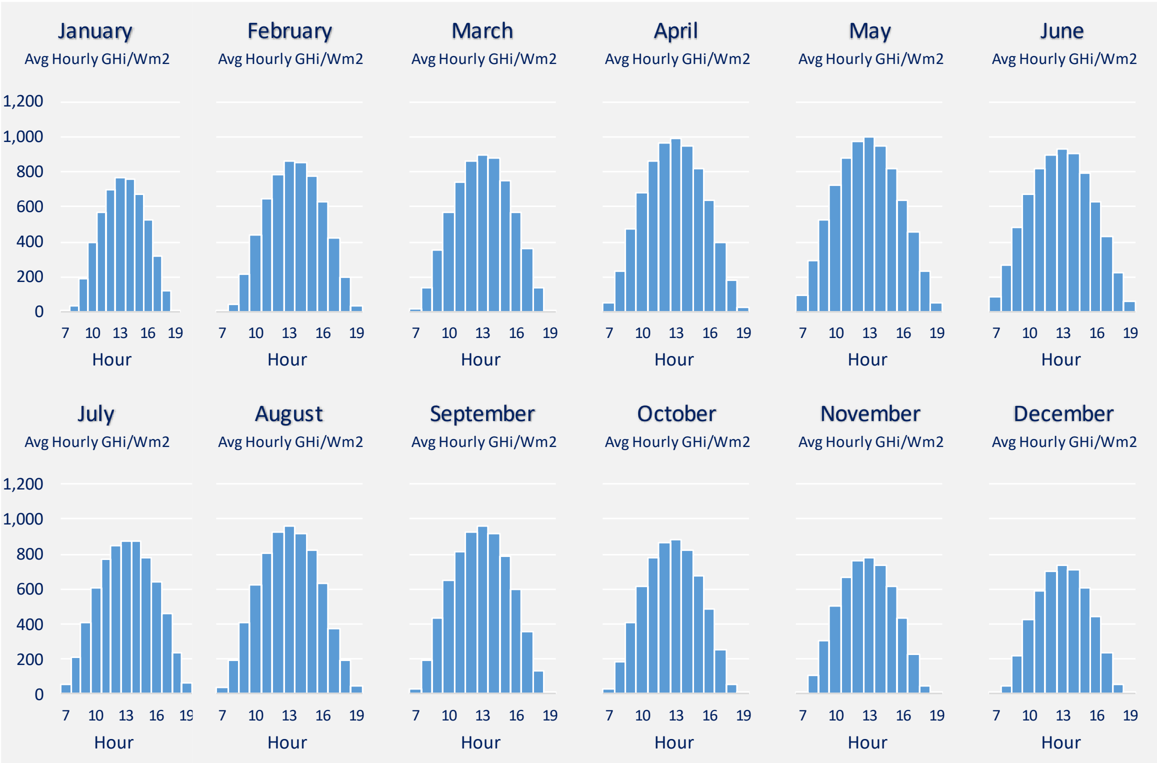
35. The analysis focused on the 10 largest bands (bands 4 to 13) organised into 10 Groups. Group 1 is band 7 the largest band, Group 2 comprises the two largest bands 6 & 7, and so on. Organising the data into 10 Groups allowed the Authority to assess the optimal size of a Residential PV initiative balancing the number of customer accounts against expected benefits. Figure 5 provides details of the bands and accounts in each Group.

Figure 5: MIS Residential Account Groups & Constituent Bands

Groups	Bands	#Accts	% 2014 MIS Accts
Group 1	*7*	29,080	5%
Group 2	*6 & 7*	58,078	10%
Group 3	*6 to 8*	85,503	14%
Group 4	*5 to 8*	112,018	18%
Group 5	*5 to 9*	137,328	22%
Group 6	*5 to 10*	160,323	26%
Group 7	*5 to 11*	181,673	30%
Group 8	*4 to 11*	201,612	33%
Group 9	*4 to 12*	220,868	36%
Group 10	*4 to 13*	237,820	39%
All Bands	*1 to 32*	369,604	61%

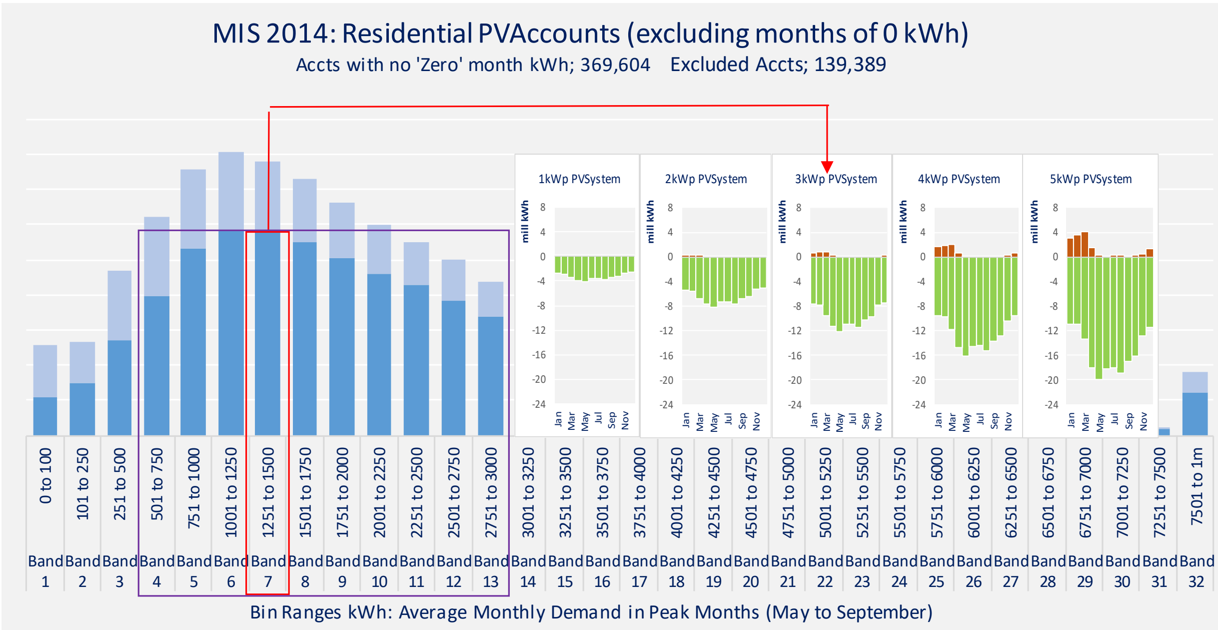
36. 1kWp, 2kWp, 3kWp, 4kWp and 5kWp PV systems were modelled using pooled hourly solar irradiation data measured at Adam and Manah during 2015 and 2016, see Figure 6. GHi is highest in May and lowest in December and is consistently available between 7am and 7pm.

Figure 6: Average Hourly Solar Irradiance (GHi) by Month – (Adam & Manah 2015/16)



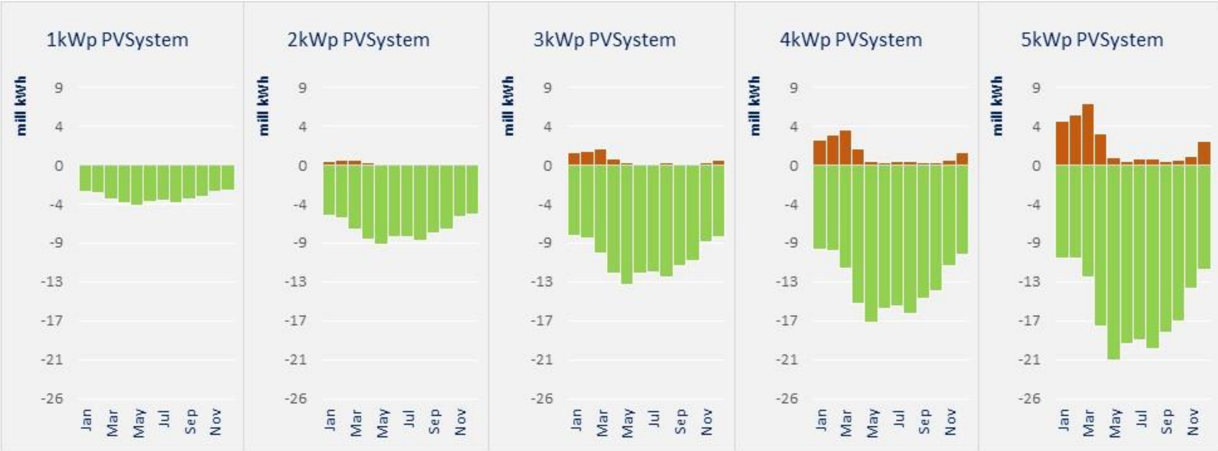
37. Monthly output of the five PV system sizes was applied to monthly consumption of individual accounts in each Group to estimate how much electricity would be consumed as self-supply or exported to a distribution system, as illustrated in Figure 7 for band 7 where green bars indicate self-supply and brown bars export.

Figure 7: Band 9 Estimated Monthly PV production – Self Supply & Surplus Export



38. Figure 8 shows the PV output profiles (self-supply and export) for 29,080 accounts in Group 1.

Figure 8: 2014 PV Self-Supply (Green Bars) and Export (Brown Bars) – Group 1



39. PV production is higher in summer months than in winter reflecting the profile of solar irradiance (GHi) in Oman. Exports increase with PV system size as larger PV systems produce more electricity relative to demand. Exports are noticeably higher in winter months reflecting lower customer demand in these months.

40. A significant proportion of PV system output can be expected to be consumed as self-supply.

41. Figure 9 presents aggregate production for each PV system size in the first year of operation. The reported GWh have been adjusted for distribution losses: self-supply is increased by 6% to reflect the avoided losses of centrally dispatched electricity, PV export is reduced by 6% to reflect losses transporting electricity to other premises. The GWh in Figure 9 reflect the quantities of centrally dispatched electricity displaced by PV, and therefore are an appropriate basis on which to assess Residential PV benefits.

Figure 9: Estimated PV Output (Central Case, adjusted for losses) – GWh

			% 2014	1 Year PV Production - GWh (Adjusted for Dloss)				
Groups	Bands	#Accts	MIS Accts	1kWp	2kWp	3kWp	4kWp	5kWp
Group 1	*7*	29,080	5%	50.0	99.8	149.2	198.1	246.5
Group 2	*6 & 7*	58,078	10%	99.9	199.2	297.6	394.8	490.9
Group 3	*6 to 8*	85,503	14%	147.1	293.4	438.6	582.2	724.3
Group 4	*5 to 8*	112,018	18%	192.6	384.0	573.6	760.8	945.9
Group 5	*5 to 9*	137,328	22%	236.1	471.1	703.9	934.1	1,161.9
Group 6	*5 to 10*	160,323	26%	275.7	550.2	822.4	1,091.9	1,358.6
Group 7	*5 to 11*	181,673	30%	312.5	623.6	932.6	1,238.5	1,541.5
Group 8	*4 to 11*	201,612	33%	346.6	691.4	1,033.2	1,371.4	1,705.9
Group 9	*4 to 12*	220,868	36%	379.8	757.7	1,132.6	1,503.7	1,871.1
Group 10	*4 to 13*	237,820	39%	409.0	816.0	1,220.1	1,620.3	2,016.6

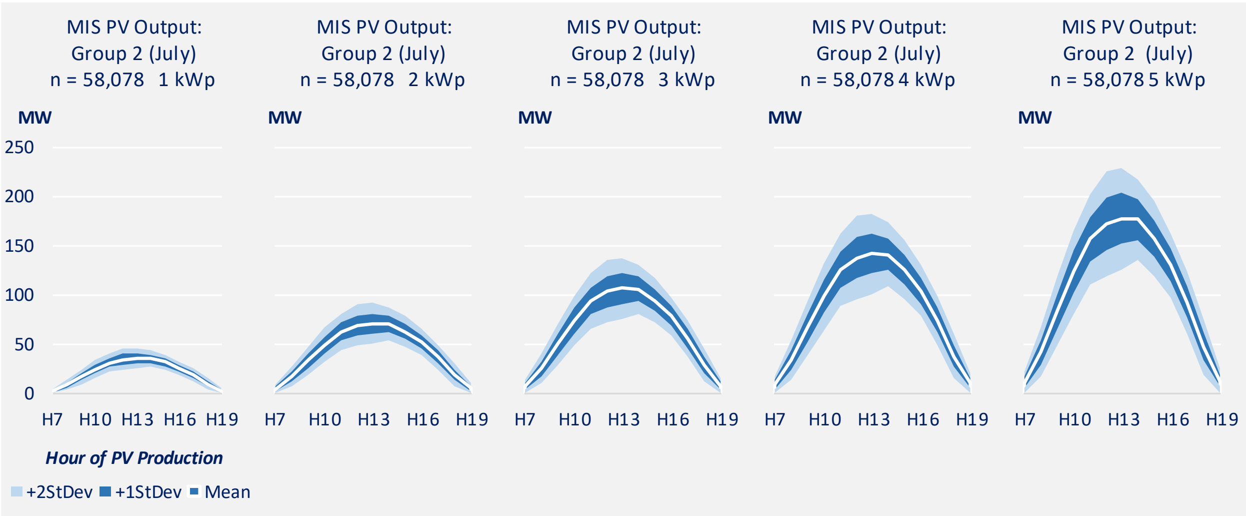
42. 3kWp PV systems installed at 58,078 accounts in Group 2 (10% of 2014 MIS Residential accounts), displace 298GWh of centrally dispatched electricity in the first year of operation, Group 7 accounts (30% of MIS Residential accounts) displace 933GWh.

Analysis Results: MIS Hourly System Demand

43. A Residential PV initiative of sufficient size has the potential to change the profile of system demand, and may reduce system peak demand. Any sustained reduction in peak demand could in turn lead to lower investment in network and generating production capacity.

44. Monthly simulation of hourly PV production, with the number of simulations equalling the number of accounts, produced production profiles for each PV system size. Figure 10 presents results for Group 2 (July GHi) for each of the five PV system sizes.

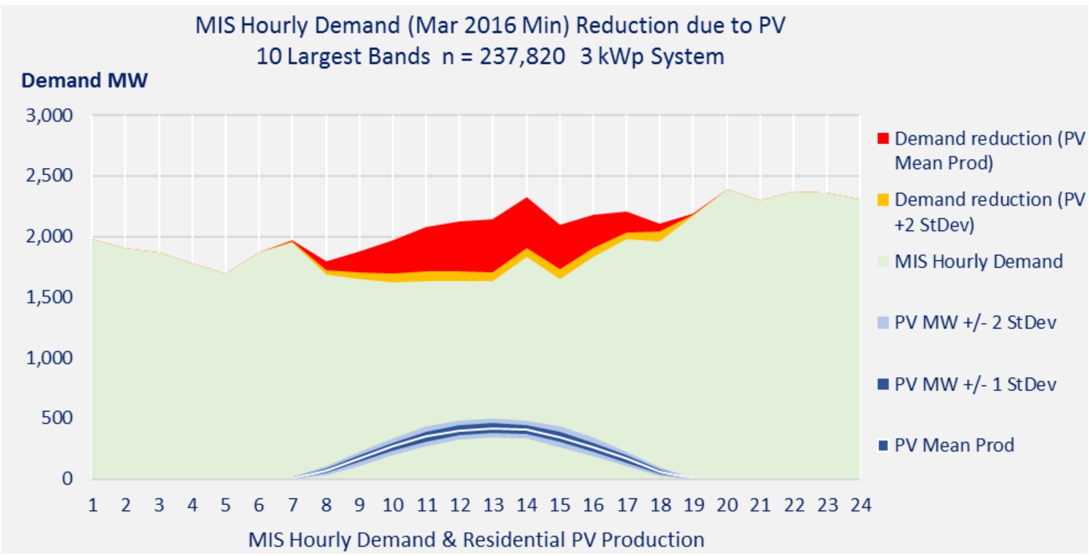
Figure 10: PV Hourly Output, Group 2 (July GHi): 1, 2, 3, 4, & 5kWp Systems



45. Variability of PV output due to variations in hourly GHi and PV losses is reflected in Figure 10 where mean hourly PV is shown within +/- 1 and 2 standard deviations. Simulated output of 58,078 1kWp systems in hour 13 in July is 36MW, 71MW for 2kWp, 107MW for 3kWp, 142MW for 4kWp and 178MW for 5kWp. These models were used to assess how Residential PV might affect the profile of MIS demand, using 2016 MIS hourly data.

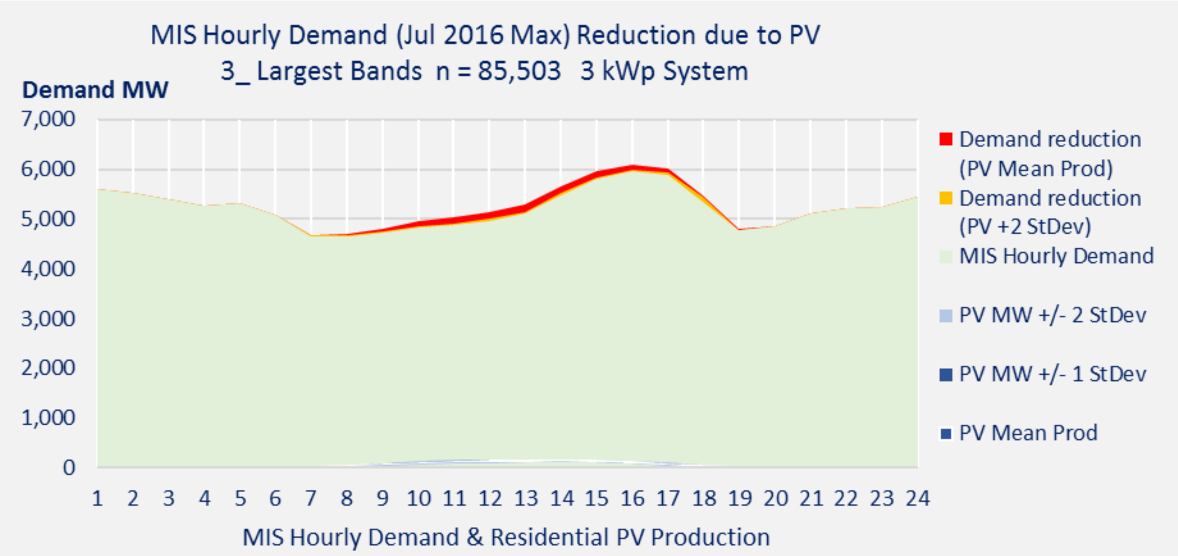
46. Figure 11 presents results for 237,820 Group 10 accounts with 3kWp PV systems operating in March (the month of lowest hourly demand in 2016).

Figure 11: MIS Demand & PV Output – 10 Largest Bands, March GHi, 3kWp PV System



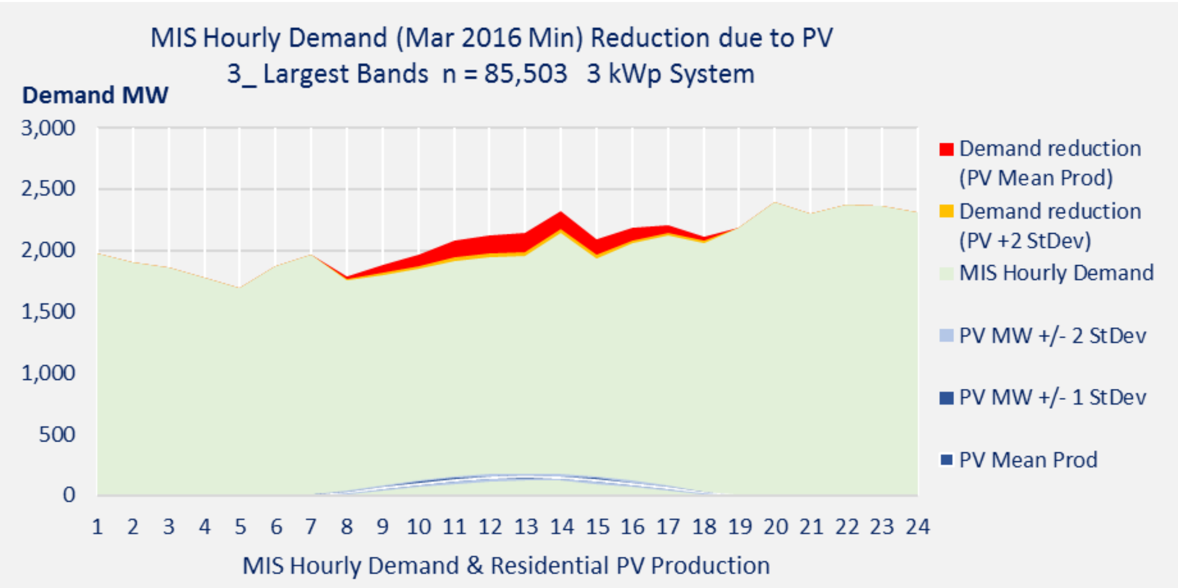
47. The red area in Figure 11 is the demand reduction due to mean PV production (see bottom of chart), the orange area is the additional reduction for PV production +2 standard deviations. Residential PV does not reduce peak demand on this day as peak demand is in hour 20 (8 pm) when PV production has ceased due to the decline in solar irradiance. Figure 12 shows demand on the day of MIS maximum demand in July 2016, and demand reductions due to 3kWp PV systems at 85,503 Group 3 accounts.

Figure 12: MIS Demand & PV Output – Group 3, July GHi, 3kWp PV System



48. PV appears to have only a negligible effect on system demand, but in fact 85,503 3kWp PV systems produce 1.1 GWh (mean estimate) during the day that reduces maximum demand by 1.8% (from 6,104MW to 5,993MW at 4pm). Figure 13 shows the day of MIS minimum demand in March 2016. 85,503 3kWp PV systems produce 1 GWh during the day, but do not reduce maximum demand that occurs at 8pm (hour 20) when PV production has ceased.

Figure 13: MIS Demand & PV Output – 3 Largest Bands, March GHi, 3kWp PV System



49. The analysis indicates that PV is particularly beneficial in summer as it may reduce system peak demand and contribute to lower network and production capacity investment.

Analysis Results: MIS Gas Saving Benefits

50. We now turn to quantify the potential gas benefits of a Residential PV initiative.

51. Figure 14 presents estimated gas savings in 1 year and over 25-years from Residential PV (note: 25-year savings reflect panel degradation of 0.5% p.a.)

Figure 14: Residential PV Gas Benefits (1 Year & 25 Years) – Sm^3 million

			Gas Savings (volumes) - million Sm^3									
		% of 2014	1kWp		2kWp		3kWp		4kWp		5kWp	
Groups	#Accts	MIS Accts	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr
Group 1	29,080	5%	14	324	27	647	41	967	54	1,283	68	1,597
Group 2	58,078	10%	27	647	55	1,290	82	1,928	109	2,557	135	3,180
Group 3	85,503	14%	40	953	81	1,901	121	2,841	160	3,771	199	4,692
Group 4	112,018	18%	53	1,247	106	2,488	158	3,715	209	4,928	260	6,127
Group 5	137,328	22%	65	1,530	130	3,051	194	4,560	257	6,051	320	7,527
Group 6	160,323	26%	76	1,786	151	3,564	226	5,328	300	7,073	374	8,801
Group 7	181,673	30%	86	2,024	172	4,040	256	6,041	341	8,023	424	9,986
Group 8	201,612	33%	95	2,245	190	4,479	284	6,693	377	8,884	469	11,051
Group 9	220,868	36%	104	2,460	208	4,908	311	7,337	414	9,741	515	12,121
Group 10	237,820	39%	112	2,649	224	5,286	336	7,904	446	10,496	555	13,064

52. For Group 2, 3kWp systems at 10% of residential premises save 82 million Sm^3 of gas in 1 year and around 2 billion Sm^3 of gas over 25 years. For Group 7 (30% of accounts and 3kWp) the expected gas saving over 25-years is an estimated 6 billion Sm^3.

53. Figure 15 presents estimates of the economic value of 25-year gas savings at a gas price of $7mMBTu and annual price escalation of 3% (savings are discounted at a SRTP of 4% real).

Figure 15: Residential PV Gas Benefits (25 Years) - Rial Omani, million

PV Production: Central Case			% 2014	NPV (4%, 25 y) OR million				
Groups	Bands	#Accts	MIS Accts	1kWp	2kWp	3kWp	4kWp	5kWp
Group 1	*7*	29,080	5%	27.1	54.1	80.8	107.3	133.5
Group 2	*6 & 7*	58,078	10%	54.1	107.9	161.2	213.9	266.0
Group 3	*6 to 8*	85,503	14%	79.7	159.0	237.6	315.4	392.4
Group 4	*5 to 8*	112,018	18%	104.3	208.1	310.7	412.2	512.5
Group 5	*5 to 9*	137,328	22%	127.9	255.2	381.4	506.1	629.5
Group 6	*5 to 10*	160,323	26%	149.4	298.1	445.6	591.6	736.1
Group 7	*5 to 11*	181,673	30%	169.3	337.9	505.2	671.0	835.2
Group 8	*4 to 11*	201,612	33%	187.8	374.6	559.8	743.0	924.2
Group 9	*4 to 12*	220,868	36%	205.8	410.5	613.6	814.7	1,013.7
Group 10	*4 to 13*	237,820	39%	221.6	442.1	661.0	877.8	1,092.6

54. For Group 2, 3kWp systems at 10% of residential premises produces gas savings over 25 years with a present value of RO 161.2 million, for Group 7, 3kWp systems at 30% of residential premises return gas savings with a present value of RO 505 million.

Analysis Results: MIS CO_2 Emission Reductions

55. A Residential PV initiative has the potential to reduce CO_2 emissions through lower natural gas use. In addition to direct environment benefits of lower CO_2, Residential PV could help Oman meet its international commitments to reduce greenhouse gas emissions. We must stress that reported CO_2 reductions are 'potential' in that they assume gas saved due to PV is not used elsewhere in Oman, is exported, or results in lower gas imports. Figure 16 presents estimated CO_2 reductions from Residential PV in 1 year and over 25 years.

Figure 16: Residential PV Gas Benefits –CO_2 Emission Reductions (million tons)

			Gas Benefits (CO_2 reduction) - Metric tons of $C0_2$ million									
		% of 2014	1kWp		2kWp		3kWp		4kWp		5kWp	
Groups	#Accts	MIS Accts	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr
Group 1	29,080	5%	0.02	0.53	0.05	1.06	0.07	1.59	0.09	2.11	0.11	2.63
Group 2	58,078	10%	0.05	1.06	0.09	2.12	0.13	3.17	0.18	4.21	0.22	5.23
Group 3	85,503	14%	0.07	1.57	0.13	3.13	0.20	4.67	0.26	6.20	0.33	7.72
Group 4	112,018	18%	0.09	2.05	0.17	4.09	0.26	6.11	0.34	8.11	0.43	10.08
Group 5	137,328	22%	0.11	2.52	0.21	5.02	0.32	7.50	0.42	9.95	0.53	12.38
Group 6	160,323	26%	0.12	2.94	0.25	5.86	0.37	8.76	0.49	11.63	0.61	14.48
Group 7	181,673	30%	0.14	3.33	0.28	6.65	0.42	9.94	0.56	13.20	0.70	16.43
Group 8	201,612	33%	0.16	3.69	0.31	7.37	0.47	11.01	0.62	14.61	0.77	18.18
Group 9	220,868	36%	0.17	4.05	0.34	8.07	0.51	12.07	0.68	16.02	0.85	19.94
Group 10	237,820	39%	0.19	4.36	0.37	8.70	0.55	13.00	0.73	17.26	0.91	21.49

56. For Group 2, 3kWp systems at 10% of residential premises reduces CO_2 emissions over 25-years by 3.2 million tons, the 25-year reduction for Group 7 is 10 million tons of CO_2. The economic benefit of lower emissions is reflected in revenue from a carbon tax applied to CO_2 in Figure 16. Tax revenue represents the value of avoided damage from CO_2. A carbon tax of US$25 ton of CO_2 (no escalation) generates the revenues in Figure 17 (revenue streams are discounted using a real SRTP of 4%).

Figure 17: Residential PV Gas Benefits – Carbon Tax Revenues: RO million

			Carbon Tax Revenue - (Tax = 25US$ ton CO_2) - RO million									
		% of 2014	1kWp		2kWp		3kWp		4kWp		5kWp	
Groups	#Accts	MIS Accts	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr	1Yr	25 Yr
Group 1	29,080	5%	0.2	1.8	0.4	6.6	0.6	9.9	0.9	13.1	1.1	16.3
Group 2	58,078	10%	0.4	3.6	0.9	13.2	1.3	19.7	1.7	26.2	2.1	32.5
Group 3	85,503	14%	0.6	5.3	1.3	19.4	1.9	29.1	2.5	38.6	3.2	48.0
Group 4	112,018	18%	0.8	6.9	1.7	25.4	2.5	38.0	3.3	50.4	4.1	62.7
Group 5	137,328	22%	1.0	8.4	2.1	31.2	3.1	46.6	4.1	61.9	5.1	77.0
Group 6	160,323	26%	1.2	9.8	2.4	36.5	3.6	54.5	4.8	72.4	5.9	90.0
Group 7	181,673	30%	1.4	11.2	2.7	41.3	4.1	61.8	5.4	82.1	6.7	102.1
Group 8	201,612	33%	1.5	12.4	3.0	45.8	4.5	68.5	6.0	90.9	7.4	113.0
Group 9	220,868	36%	1.7	13.6	3.3	50.2	4.9	75.1	6.5	99.6	8.1	124.0
Group 10	237,820	39%	1.8	14.6	3.6	54.1	5.3	80.8	7.1	107.4	8.8	133.6

57. Group 2 3kWp systems return carbon tax revenue over 25 years with a present value of RO 20 million, Group 7 carbon tax revenue over 25-years is RO 62 million.

Analysis Results: Reductions in Tariff Revenue & Customer Bills

58. The impact of Residential PV on Permitted Tariff revenues and Customer bills was assessed, changes in tariff revenue are presented in Figure 18.

Figure 18: Impact of Residential PV on Permitted Tariff Revenue – RO million & %

			A: Residential Tariff Revenue - RO m						B: Reductions in Tariff Revenues - %				
Groups	*Bands*	*Accounts*	*NO PV*	1kWp	2kWp	3kWp	4kWp	5kWp	1kWp	2kWp	3kWp	4kWp	5kWp
Group 1	*7*	29,080	3.4	3.0	2.5	2.1	1.7	1.4	-14%	-27%	-39%	-50%	-59%
Group 2	*6 & 7*	*58,078*	6.3	5.3	4.4	3.6	2.9	2.3	-15%	-29%	-42%	-53%	-63%
Group 3	*6 to 8*	85,503	10.0	8.7	7.4	6.1	5.1	4.1	-14%	-27%	-39%	-50%	-59%
Group 4	*5 to 8*	112,018	12.1	10.4	8.7	7.1	5.8	4.6	-15%	-29%	-41%	-53%	-62%
Group 5	*5 to 9*	137,328	16.2	14.0	11.9	9.9	8.2	6.7	-14%	-27%	-38%	-49%	-59%
Group 6	*5 to 10*	160,323	20.3	17.7	15.3	13.0	10.9	9.1	-13%	-25%	-36%	-46%	-55%
Group 7	*5 to 11*	*181,673*	24.6	21.6	18.8	16.2	13.8	11.6	-12%	-23%	-34%	-44%	-53%
Group 8	*4 to 11*	201,612	25.8	22.5	19.5	16.6	14.1	11.8	-13%	-25%	-36%	-45%	-54%
Group 9	*4 to 12*	220,868	30.1	26.5	23.1	20.0	17.1	14.6	-12%	-23%	-34%	-43%	-52%
Group 10	*4 to 13*	237,820	34.3	30.4	26.7	23.3	20.2	17.4	-11%	-22%	-32%	-41%	-49%

59. With no PV, 58,078 Group 2 accounts generate tariff revenue of RO 6.3 million. With 3kWp systems, tariff revenue falls 42% to RO 3.6 million. Tariff revenue for Group 7 accounts with 3kWp systems falls from RO 24.6 million to 16.2 million, a 34% reduction. Figure 19 presents average reductions in annual residential customer bills (note that no allowance is made for remuneration of surplus electricity to a distribution system).

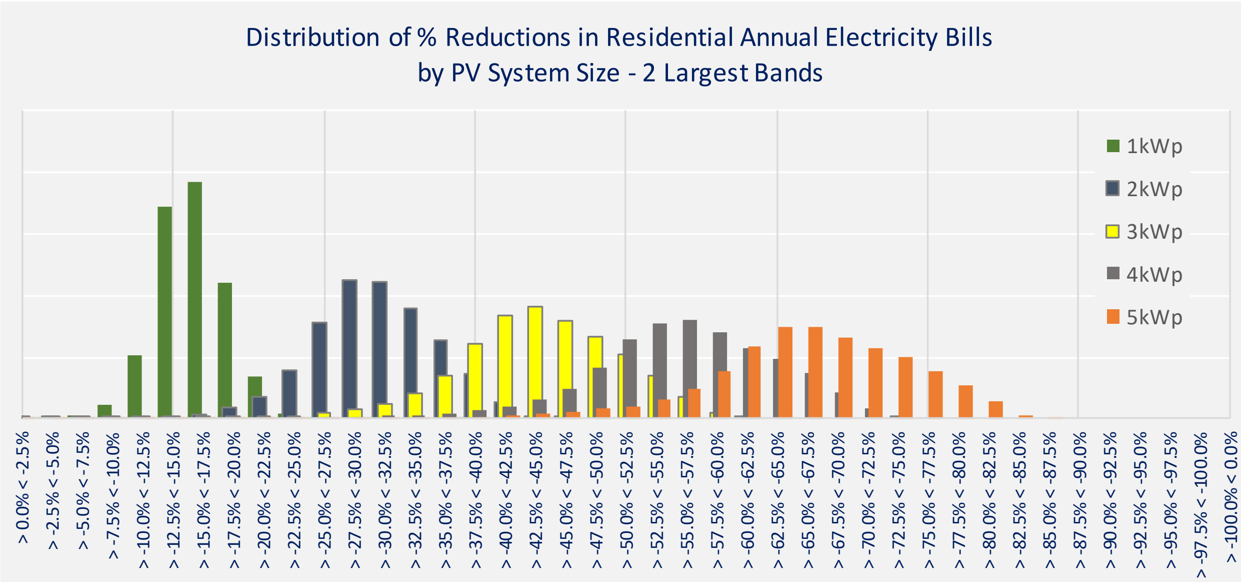
Figure 19: Impact of Residential PV on Electricity Bills – %

		Tariff Rev	Avg Bill (no PV)	A: Reductions in Annual Average Bills - %				
Group	#Accts	RO million	12 mths RO	1kWp	2kWp	3kWp	4kWp	5kWp
Group 1	29,080	3.4	118.0	-14%	-27%	-39%	-50%	-59%
Group 2	58,078	6.3	107.8	-15%	-29%	-42%	-53%	-63%
Group 3	85,503	10.0	117.5	-14%	-27%	-39%	-50%	-59%
Group 4	112,018	12.1	108.4	-15%	-29%	-41%	-53%	-62%
Group 5	137,328	16.2	117.8	-14%	-27%	-38%	-49%	-59%
Group 6	160,323	20.3	126.7	-13%	-25%	-36%	-46%	-55%
Group 7	181,673	24.6	135.2	-12%	-23%	-34%	-44%	-53%
Group 8	201,612	25.8	127.9	-13%	-25%	-36%	-45%	-54%
Group 9	220,868	30.1	136.3	-12%	-23%	-34%	-43%	-52%
Group 10	237,820	34.3	144.2	-11%	-22%	-32%	-41%	-49%

60. The Customer bill reductions in Figure 19 mirror the tariff revenue reductions in Figure 18. Annual bills of Group 2 customers with 3kWp PV systems decline on average by 42%, from RO 108 to RO 63. Average bills of Group 7 customers decline by 34%.

61. There is wide variation in the distribution of percentage bill reductions and it would be misleading to expect that all customers would benefit from the average reductions in Figure 19. To emphasise this point Figure 20 shows the distribution of percentage bill reductions for Group 2 customers for each PV system size.

Figure 20: Variation of % Reductions in Group 2 Customer Bills by PV System Size



62. For a given annual kWh consumption, the percentage annual bill reduction increases with PV system size. However, the significant overlap of distributions in Figure 20 suggests that bill reductions for customers with large PV systems may sometimes be lower than for customers with smaller PV systems, reflecting the variation in annual consumption within the Group.

63. The reported bill reductions are, nevertheless, a helpful indication of how customers are expected to benefit from the initiative, but the reductions should be reported in the context of the analysis and treated with caution.

64. The Residential PV initiative proposed by the Authority would reduce Permitted Tariff revenues, which has implications for network operators and annual subsidy, while reducing bills for customers. We discuss this point below when considering how much customers should be asked to contribute to the cost of installing a PV system at their premises.

Summary of Residential PV Gas Benefits

65. Our analysis suggests a Residential PV initiative could deliver the following benefits:

(i) Gas savings over 25 years of between **2 billion Sm^3** (Group 2 accounts, 3kWp systems) and **6 billion Sm^3** (Group 7 accounts, 3kWp systems);

(ii) Gas savings over 25-years with a present value between **RO 161 million** (Group 2 accounts, 3kWp systems) and **RO 505 million** (Group 7 accounts, 3kWp systems)[14], equivalent to $2,700 or RO 7,200 per account; and

(iii) CO_2 emission reductions over 25-years of between **3.2 million tons** (Group 2 accounts, 3kWp systems) and **10 million tons** (Group 7 accounts, 3kWp systems).

66. Additional benefits of lower network and production capacity investment are not included in our estimates of expected benefits, nor are the benefits customers will derive from long term reductions in electricity bills.

[14] See Appendix 2 for results and sensitivity analysis for Group 2, Group 7 and Group 10 benefits.

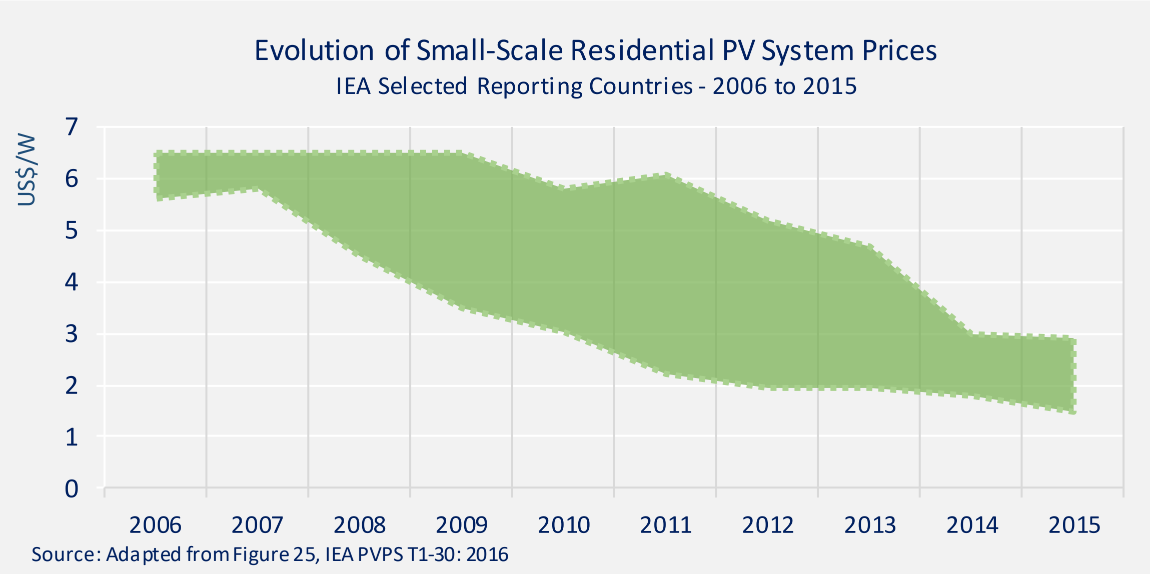
Section 4: Assessment of Residential PV System Costs

67. A review of international trends in Residential PV costs highlighted three key points: first, is the rapid decline in costs over the past decade; second, is significant cross-country variation in costs; and third, are large cross-country differences in 'hard' and 'soft' costs.

Trends in Residential PV System Costs

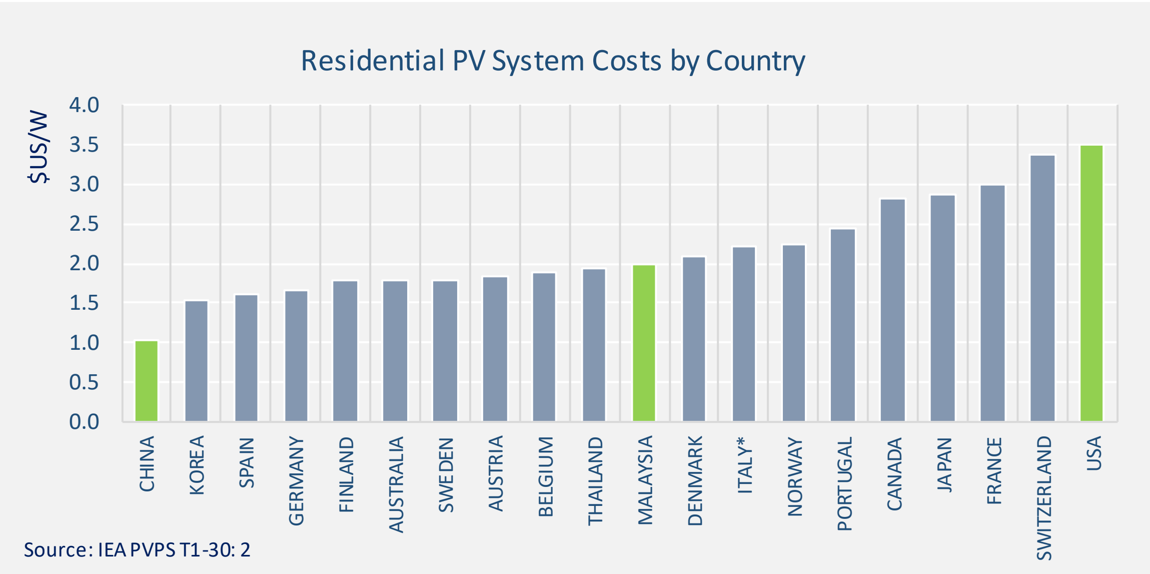
68. Figure 21 shows a high-low range of Residential PV costs as reported by IEA selected countries.

Figure 21: Trends in Residential PV System Costs – 2006 to 2015



69. From a high-low range of 6.5 to 5.6 US$/W in 2006, costs fell to 2.6 to 1.5 US$/W in 2015, a 65% reduction in average costs. Cross-country cost variations in 2015 are shown in Figure 22.

Figure 22: Residential PV System Costs by Country - 2015

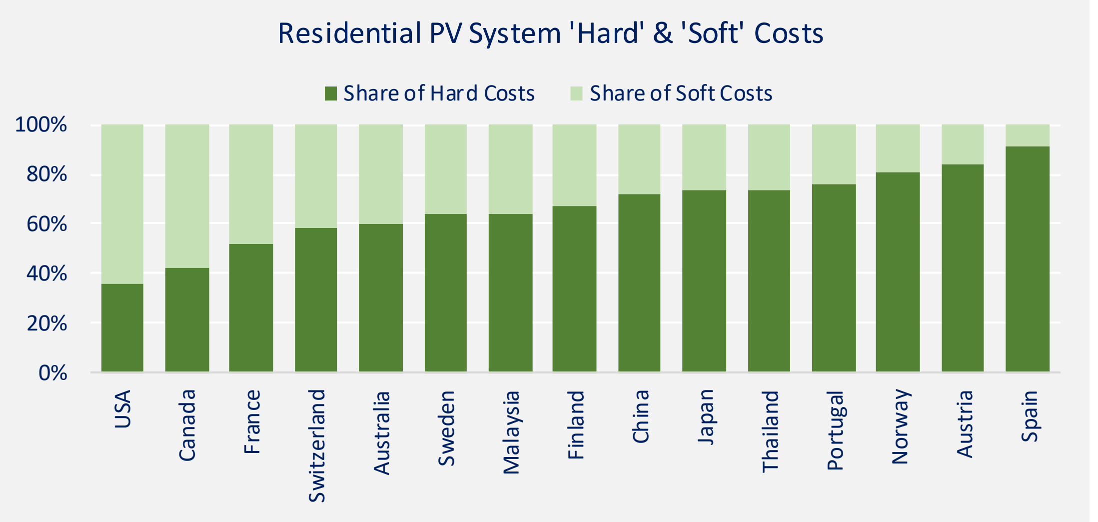


70. In 2015, Residential PV costs were lowest in China (1 US$/W) and highest in the USA (2.9 US$/W). Malaysia is at the centre of the cost range with system costs of 2 US$/W.

Components Costs of Residential PV Systems

71. PV system costs in Figure 22 mask significant differences in 'hard' costs (modules, inverters and other components) and 'soft' costs (installation and commissioning). Figure 23 shows the respective contribution of 'hard' and 'soft' costs to total system costs in Figure 22.

Figure 23: Residential PV System 'Hard' and 'Soft' Costs - 2015



Source: Figure 26, IEA PVPS T1-30: 2

72. Soft costs account for 64% of USA Residential PV system costs, but just 9% of Residential PV system costs in Spain. The cost of installing, configuring and setting up residential PV systems can make a significant contribution to total costs: the four countries in Figure 23 with the highest shares of soft costs (USA, Canada, France and Switzerland) account for four of the five highest total system costs in Figure 22.

73. There is an important message here for Oman: careful management of 'soft' cost services such as system installation and commissioning will help constrain total costs and maximise benefits. The Authority will take steps to ensure commissioning and installation services are procured efficiently and that participating entities have the skills and experience required to ensure Residential PV systems operate to their maximum potential.

Section 5: Residential PV Support Mechanisms

74. A wide range of policies and mechanisms have evolved to support renewable energy deployment globally including feed-in schemes, net metering and net billing schemes, and fiscal policies such as grants, loans and tax incentives[15].

75. REN21 identify 146 countries with renewable policies in place in 2015[16] and 110 jurisdictions that have enacted feed-in policies that remains the most widely adopted regulatory support mechanism. Tendering is preferred to feed-in policies in a growing number of countries and REN21 report significant growth in the number of residential and industrial electricity customers who produce their own electricity.

76. Many countries increased their renewable energy targets in 2015 and policy makers continue to evaluate the effectiveness of renewable support mechanisms. REN21 report increased momentum towards competitive tendering and that many countries have amended the terms of Feed in Tariffs (FiT) and many more are under review. REN21 also note that in response to EU recommendations and public opinion, Germany removed FITs for solar PV projects of 0.5-10MW in favour of new tender schemes[17].

Support Mechanism for Oman Residential PV Initiative

77. The Authority has considered whether any of the established PV support mechanisms would be appropriate for the Residential PV initiative:

    i. **Feed in Tariffs**: typically provide payments for electricity supplied to the grid at agreed rates that are sometimes subject to indexation. FIT have proved to be effective in advancing the deployment of renewable technologies in some countries but have been criticised by economists for providing weak incentives to reveal and reduce costs and for providing windfall gains to some recipients.

       The Authority does not propose FiT for the Residential PV initiative given that most PV production is expected to be consumed as self-supply and only a small proportion exported. FiT may be appropriate for larger PV systems provided the terms of FiT contracts can be competitively tendered;

    ii. **Net Metering / Net Billing**: Net metering schemes provide customers with credits for PV electricity exported to the grid that can be used to reduce charges for electricity supplied to them in other periods. Net billing is similar to net metering but typically applies differential tariffs for electricity supplied to a customer and electricity exported to the grid.

       The Authority does not propose to use Net Metering or Net Billing for the Residential PV initiative given the expected magnitude of PV self-supply, the complexity of accounting for net metering balances, and give the disparity between the economic cost of supply and the Residential Tariff.

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15 REN21 2016, page 20
16 REN21 2016, page 107
17 REN21 2016, page 109

iii. **Renewable Levy**: a Residential PV initiative could be financed by applying a 'per kWh levy' on supply to all electricity customers – as in Germany. It could be argued that all electricity customers would share the environmental benefits and derive further benefit from distributed PV generation that would reduce peak demand growth and help to constrain future costs.

The Authority does not propose to pursue a Renewable Levy that would increase the electricity costs of all customers, would constitute a cross subsidy, and would require time to secure the necessary approvals for its implementation.

iv. **Accelerated Subsidy Adjustment**: is an arrangement where, in anticipation of future subsidy reductions, an agreed amount of future subsidy is provided to the Authority to fund an initial stage of the initiative. Customers participating in the initiative would be asked to contribute to the cost of installing a PV system at their premises, contributions would be a multiple of (i) customer bills, or (ii) the present value of anticipated bill savings over three or five years. Thereafter, customers would receive the full benefit of ongoing bill reductions.

Once an initial tranche of Residential PV systems is installed and demonstrating satisfactory performance, the PV systems would be offered as an investment opportunity to investment funds who would recover their investment and an agreed competitive rate of return from payments aligned to PV system output reflecting the monetised economic benefits described above. The Authority will utilise funds from the sale of the initial tranche of PV systems to finance a further tranche of Residential PV, and so on until the initiative target is met.

The Authority believes this framework could be an effective way of implementing a Residential PV initiative in Oman, subject to agreement with government on a basis for bringing forward future subsidy savings and a mechanism to translate monetised economic benefits to revenue payments sufficient to remunerate investment funds.

Role of the Authority

78. The Authority intends to play a prominent role in supervising, managing and progressing the Residential PV initiative, for the following reasons:

i. **Subsidy administration**: The Authority is responsible for calculating and administering electricity subsidy and is well placed to ensure the wider economics benefits of the initiative are properly reflected in the calculation and reporting of subsidy. The overriding aim of the Residential PV initiative is to reduce electricity subsidy in the medium and long term;

ii. **Price Controls and Subsidy**: a successful Residential PV initiative will require the price controls of licensed distributors and suppliers to be adjusted to reflect reduced volumes of distributed electricity, and lower tariff revenues. The Authority will want to ensure licensees perform their functions efficiently and cooperate with the initiative and have sufficient resources to do so; and

iii. **Minimise implementation risks and maximise PV system performance:** it will be important to ensure the procurement of PV system components (hard costs) and recruitment of contractors to install and commission systems (soft costs) are subject to effective procurement competition. The Authority will ensure rigorous process are followed for system installation, asset registration, and for the monitoring and analysis of performance data; and

iv. **Safeguard customer interests:** the initiative will require the participation and cooperation of large numbers of residential customers. It will be important to ensure customer interests and afforded sufficient priority during the installation process and delivering expected reductions in bills.

79. As part of the consultation process the Authority is consulting and engaging with government departments to finalise details of the proposed initiative including the structure and terms of the proposed transactions framework.

Section 6: Summary & Conclusions

81. Based on the analysis described above and having considered the answers to the analysis questions in Section 3, the Authority proposes a Residential PV initiative as follows:

i. The phased installation of 2kWp – 4kWp PV systems at the premises of around 10% to 30% of residential customers, 58,078 (Group 2) to 181,673 (Group 7) accounts respectively;

ii. Funding for an initial phase of the initiative would comprise (i) an advance of future gas saving benefits and subsidy reductions and (ii) customer contributions based on a multiple of either (a) annual bills, or (b) the present value of five-years of anticipated bill savings. Payback periods for customer contributions would be between 3 to 5 years after which customers would continue to receive the full benefit of bill reductions;

iii. The Authority will supervise the installation of an initial tranche of Residential PV systems that, once installed and demonstrating satisfactory performance, would be offered as an investment opportunity to investment funds who would recover their investment, and an agreed competitive rate of return, from payment streams aligned to PV system output reflecting the monetised economic benefits described in this paper. The Authority would utilise funds from the sale of the initial tranche of PV systems to finance a further tranche of Residential PV, and so on until the initiative target is achieved. Work is ongoing to clarify and finalise details of the transactions framework;

82. Our analysis suggests a Residential PV initiative could deliver the following benefits:

(i) Gas savings over 25 years of between **2 billion Sm^3** (Group 2 accounts, 3kWp systems) and **6 billion Sm^3** (Group 7 accounts, 3kWp systems);

(ii) The present value of gas savings over 25-years is between **RO 161 million** (Group 2 accounts, 3kWp systems) and **RO 505 million** (Group 7 accounts, 3kWp systems)[18];

(iii) CO_2 emission reductions over 25-years of between **3.2 million tons** (Group 2 accounts, 3kWp systems) and **10 million tons** (Group 7 accounts, 3kWp systems);

(iv) Average reductions in annual customer bills of between **42%** (Group 2 accounts, 3kWp systems) and **34%** (Group 7 accounts, 3kWp systems); and

(v) Some reduction in system peak demand in summer months, and lower system demand in all months during hours when solar irradiation is available. Any reduction in system peak demand would provide additional benefits in the form of lower investment in electricity networks and production capacity.

83. The reported costs of small scale Residential PV systems are between 1US$ per W (China) and 3US$ per W (USA). Our estimates of 25-year gas saving benefits from 3kWp systems equate to US$2,777 or RO 7,200 per account, within the range of reported PV system costs and suggests that even without incorporating environmental benefits or savings in network and production capacity investment, the benefits of a Residential PV initiative may exceed its costs; and

[18] See Appendix 2 for results and sensitivity analysis for Group 2, Group 7 and Group 10 benefits.

84. The Authority understands some residential customers may wish to install PV systems for environmental and other reasons. To support this, the Authority is preparing to implement the following scheme in addition to the Residential PV initiative outlined above:

(i) Customer funded PV systems installed at residential premises will, subject to compliance with certain criteria, be eligible for remuneration at the relevant BST for PV production exported to the grid;

(ii) To qualify for the scheme, customers must demonstrate that PV systems comply with new renewable standards and connection conditions approved by the Authority;

(iii) PV systems participating in the scheme must incorporate approved metering systems to meter hourly PV export to the grid to facilitate settlement with time based elements of the BST; and

(iv) The scheme will be subject to capacity limits and implemented in phases to ensure the deployment of residential PV systems does not compromise the operation and performance of distribution systems to which they connect.

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Trends 2016 In Photovoltaic Applications
SURVEY REPORT OF SELECTED IEA COUNTRIES BETWEEN 1992 AND 2015
IEA PVPS T1-30:2016

Comparing Prices and Costs of Solar PV in Japan and Germany
RENEWABLE ENERGY INSTITUTE, JAPAN
REI (2016)

U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016
NREL
NREL/PR-6A20-67142 (2016)

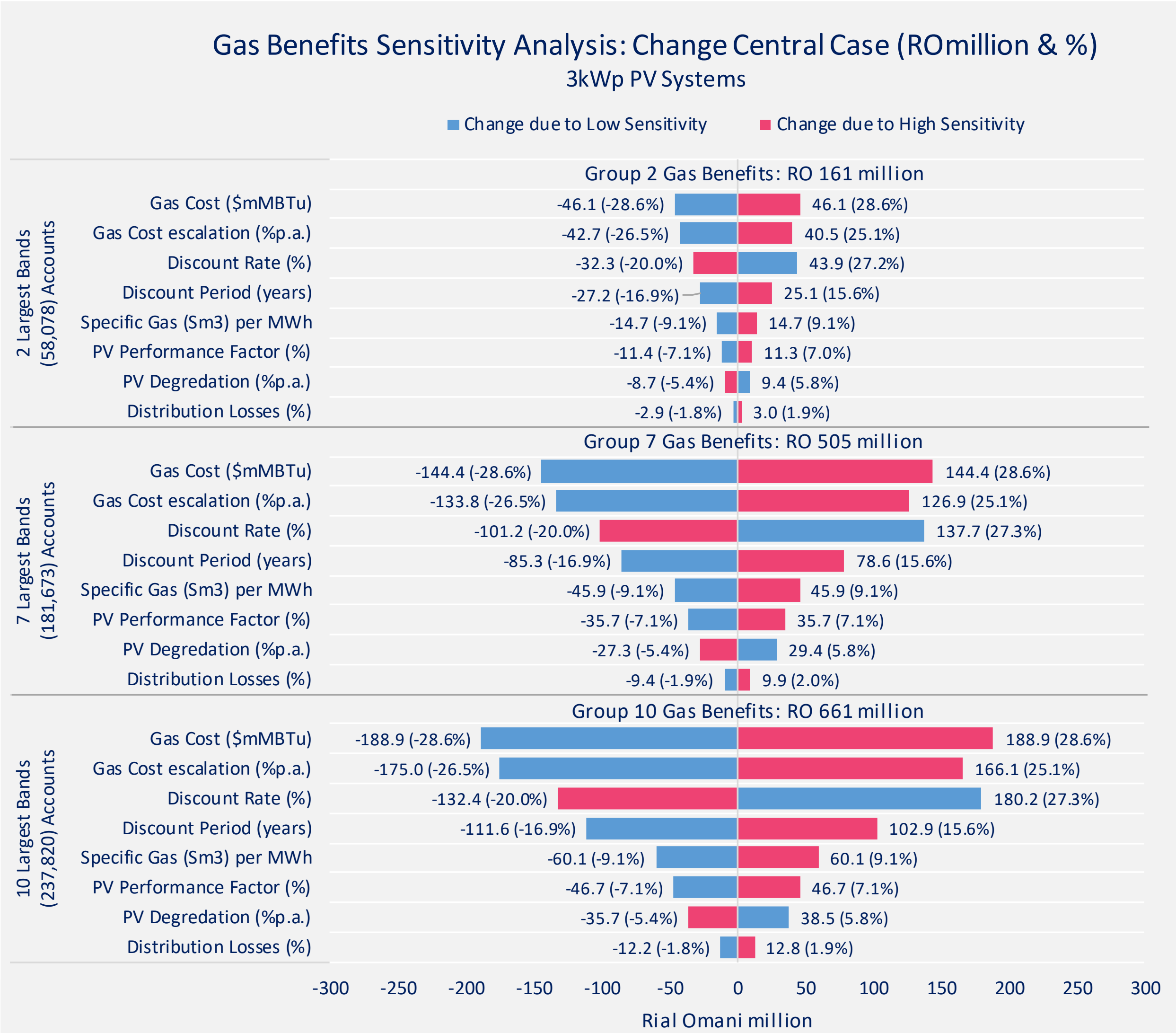
Annex B: Methodology, Models & Data

This Annex is available as a separate document and is available from the Authority on request.

Appendix 1: MIS Residential Accounts Database - 2014

	Bin Ranges	Customer Accounts: No Months with Zero kWh			
		n =	369,604		Excluded
Bands	Average Monthly kWH May to Sept	n	%Total	%Cum	Accts
Band 1	0 to 100	5,439	1.5%	1.5%	7,345
Band 2	101 to 250	7,397	2.0%	3.5%	6,014
Band 3	251 to 500	13,562	3.7%	7.1%	9,981
Band 4	501 to 750	19,939	5.4%	12.5%	11,062
Band 5	751 to 1000	26,515	7.2%	19.7%	11,464
Band 6	1001 to 1250	28,998	7.8%	27.6%	11,252
Band 7	1251 to 1500	29,080	7.9%	35.4%	9,975
Band 8	1501 to 1750	27,425	7.4%	42.8%	8,981
Band 9	1751 to 2000	25,310	6.8%	49.7%	7,764
Band 10	2001 to 2250	22,995	6.2%	55.9%	6,920
Band 11	2251 to 2500	21,350	5.8%	61.7%	6,178
Band 12	2501 to 2750	19,256	5.2%	66.9%	5,680
Band 13	2751 to 3000	16,952	4.6%	71.5%	4,855
Band 14	3001 to 3250	15,070	4.1%	75.6%	4,254
Band 15	3251 to 3500	13,047	3.5%	79.1%	3,663
Band 16	3501 to 3750	11,352	3.1%	82.2%	3,158
Band 17	3751 to 4000	9,740	2.6%	84.8%	2,804
Band 18	4001 to 4250	8,462	2.3%	87.1%	2,355
Band 19	4251 to 4500	7,280	2.0%	89.1%	2,127
Band 20	4501 to 4750	6,147	1.7%	90.7%	1,793
Band 21	4751 to 5000	5,274	1.4%	92.1%	1,517
Band 22	5001 to 5250	4,426	1.2%	93.3%	1,252
Band 23	5251 to 5500	3,808	1.0%	94.4%	1,129
Band 24	5501 to 5750	3,187	0.9%	95.2%	927
Band 25	5751 to 6000	2,690	0.7%	96.0%	851
Band 26	6001 to 6250	2,181	0.6%	96.6%	725
Band 27	6251 to 6500	1,869	0.5%	97.1%	632
Band 28	6501 to 6750	1,552	0.4%	97.5%	560
Band 29	6751 to 7000	1,283	0.3%	97.8%	460
Band 30	7001 to 7250	1,038	0.3%	98.1%	346
Band 31	7251 to 7500	855	0.2%	98.3%	376
Band 32	7501 to 1m	6,125	1.7%	100.0%	2,989
	Totals	369,604			139,389

Appendix 2: Results and Sensitivity Analysis (Central Case, 3kWp) Groups 2, 7, & 10



	Sensitivity Values		
Sensitivity Item	Low	Central	High
Gas Cost ($mMBTu)	5.0	7.0	9.0
Gas Cost escalation (%p.a.)	0%	3%	5%
Discount Rate (%)	2%	4%	6%
Discount Period (years)	20	25	30
Specific Gas (Sm3) per MWh	250	275	300
PV Performance Factor (%)	65%	70%	75%
PV Degredation (%p.a.)	0.0%	0.5%	1.0%
Distribution Losses (%)	4%	6%	8%