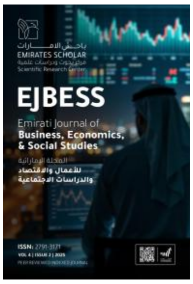

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The approach for Abu Dhabi's solar energy: Centralised or Decentralised

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ABSTRACT

This paper evaluates the economic viability of decentralised solar systems in Abu Dhabi. By analysing levelised cost of electricity (LCOE), net present value (NPV), and internal rate of return (IRR) across customer groups, it finds that while rooftop solar generation is not yet cost-effective for heavily subsidised sectors, it remains viable for industrial and commercial users. The study suggests that subsidy reform could significantly improve the financial appeal of decentralised systems, aligning with Abu Dhabi's decarbonisation targets under the UAE Energy Strategy 2050.

Keywords: *renewable energy, solar energy, decentralised solar, centralised solar, LCOE, Abu Dhabi*

I. Introduction

Solar energy refers to the heat and electricity produced by harnessing sunlight through specific technologies. It is generated by capturing and converting solar radiation into usable power. The electricity-producing solar systems, which this paper focuses on, primarily use two methods: Photovoltaics (PV) and Concentrated Solar Power (CSP) [1].

The global installed generation capacity of solar energy is divided between centralised (also called "utility scale") and decentralised systems (also called "distributed generation").

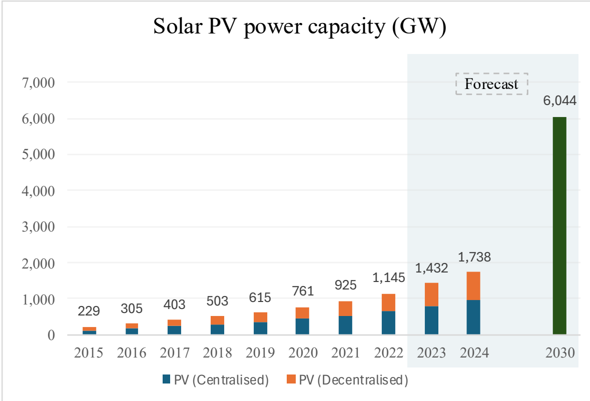
Centralised solar plants generally refer to large-scale installations for sunlight-based electricity generation. These systems tend to generate massive amounts of electricity, potentially displacing the use of carbon intensive fossil fuel-powered plants. Centralised solar plants often benefit from economies of scale as well, which lower costs and make solar energy more competitive against traditional power sources.

Decentralised solar systems offer a more localised approach, as they involve setting up PV panels at distributed locations, usually closer to the final consumers. By generating electricity on-site, these systems reduce the need for power from the grid, which may have been generated using fossil fuels or other forms of low carbon energy (such as nuclear), and usually suffer from transmission losses.

Globally, solar PV is equally popular in both centralised and decentralised formats. Figure 1 shows that the split between decentralised and centralised solar PV is about 50:50. In Abu Dhabi, however, decentralised solar PV is much less popular than centralised solar. In 2020, decentralised (Rooftop) PV on government buildings reached 2.94 MW by 2020 which is less than 1% of the Noor solar farm capacity of 1,177 MW alone [2] [14].

Accordingly, this paper asks the following questions. Why is there "a preference for large-scale projects" [3] (centralised solar, utility scale) over decentralised solar (distributed generation) [3]? Why is Dubai's decentralised (rooftop PV) scheme apparently more successful than Abu Dhabi's [2]? Is decentralised solar still not economically viable given the low electricity tariffs [6]? Is centralised solar so cheap that decentralised solar is not worthwhile [10]? Is the net metering policy unattractive or useless [14]? Are there technical, behavioural, and/or societal issues that negatively impact the deployment of distributed solar PV [4]?

Figure 1: Historical uptake of global solar energy capacity (GW) by type of generation system and 2030 target for net zero [5]

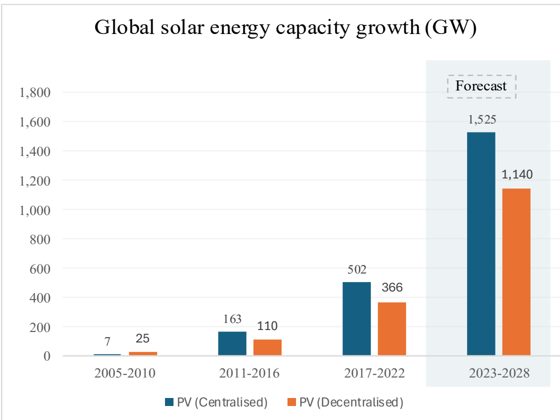


II. Literature Review

A. Global Solar Growth

The International Energy Agency (IEA) forecasts solar energy capacity additions to increase three-fold by 2028 compared to the 2022 levels, as indicated in Figure 2.

Figure 2: Forecast for global solar energy installed capacity additions (GW) [7]



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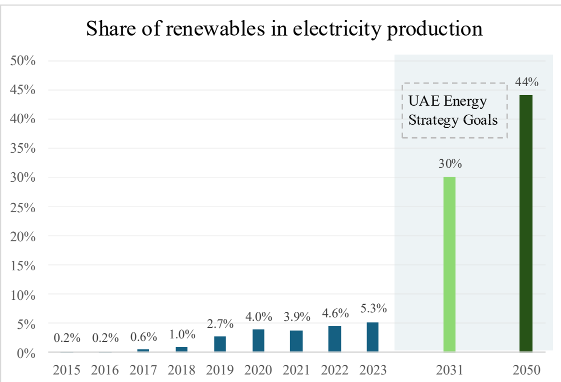
B. Sun shining on UAE ambitions?

The potential of solar radiation in United Arab Emirates (UAE) is significant, with the global horizontal irradiance (GHI), a standard measure of solar radiation, of approximately 6.045 kWh/m^2 per day [17]. UAE has set the target to achieve net zero for energy and water sectors by 2050. This commitment is included within the UAE Energy Strategy 2050 [8].

The net zero commitment forms the basis for the measures that UAE government is taking to drive penetration of decentralised renewable energy generators (e.g. rooftop solar panels and solar water heating). Solar energy has also been identified as a priority area by Ministry of Climate Change and Environment (MOCCAE) in their National Climate Change Plan of the United Arab Emirates and has been included as one of its key Long-term actions (2030-2050) [9].

In the Electricity 2024 report, IEA forecasted that the CO_2 intensity from electricity in UAE is expected to fall below 400g CO_2/kWh by 2026 [11]. The UAE Government has further set the target to reduce the CO_2 emissions to 270g CO_2/kWh by 2030 [8]. In 2023, the UAE updated its National Energy Strategy to include an interim goal of raising the contribution of renewable energy in the total energy mix to 30% by 2031 [21], to augment the initial aim of achieving 44% share of renewable energy by 2050, as in Figure 3.

Figure 3: UAE share of renewable energy (%) in total electricity production [20] and UAE Energy Strategy goals

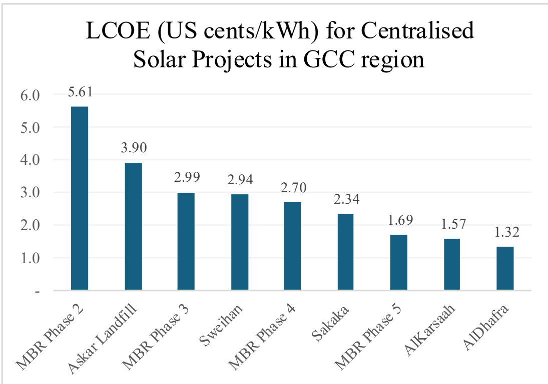


The Emirates Water and Electricity Company (EWEC) has also set the target to increase Abu Dhabi's total solar power capacity to 7 GW by 2030 [12].The Noor Abu Dhabi power plant, located at Sweihan, began commercial operations in April 2019. It covers an area of 8 square kilometres and uses 3.2 million solar panels to produce approximately 1 gigawatt (AC) of power [18]. The Mohammed bin Rashid Al Maktoum Solar Park is the largest single-site solar park in the world, based on the Independent Power Producer (IPP) model, and has a planned production capacity of 5,000 MW by 2030 [13].

C. Record-breaking LCOEs in UAE and GCC?

Researchers and industry professionals use levelised cost of energy (LCOE), a standard metric to measure the average net present cost of electricity generation for the generation system over its lifetime [14][13]. In Figure 4, we showcase the LCOE (US cents/ kWh) for some of the key centralised solar energy generation projects in the Gulf Cooperation Council (GCC) region.

Figure 4: LCOE (US cents/ kWh) for centralised solar energy projects in the GCC region [19]



Studies on UAE's current policy framework regarding the adoption of renewable energy, specifically decentralised solar, indicate that implementing a unified renewable energy policy including a feed-in tariff (FiT) mechanism and net metering could significantly enhance the adoption of decentralised solar energy generation across all of the UAE's electricity authorities [23]. As a potential policy adjustment, incentivizing rooftop solar installations on residential and commercial buildings could contribute to the energy mix while empowering communities and individuals to participate in the renewable energy transition [26].

D. Is bigger better? Or is there an LCOE problem?

On an LCOE basis, decentralised solar energy could be 4 times higher than its centralised counterpart.

However, the LCOE is misleading because it measures the cost 'at production' rather than the 'landed' (delivered) cost, which is more important for customers and policy makers [24]. For example, LCOEs for centralised solar generally exclude grid-related transportation, balancing, intermittency, losses, and peak power costs [25]. Another cost metric, LFSCOE (Levelised Full System Cost of Electricity, "System LCOE") has been proposed to improve comparability [26]. In Germany, the LFSCOE for centralised solar is 43 times greater ($/MWh, 1548 / 36) than its LCOE [27]. Accordingly, the actual "landed cost" of solar may, in fact, be *higher* for centralised systems than decentralised systems [10].

By generating electricity on-site, decentralised systems can reduce the need for power from the grid, which may have been generated using fossil fuels or other forms of low carbon energy (such as nuclear).

III. Methodology

A. How do we calculate LCOEs?

Decentralised solar systems such as residential rooftop solar plants face inherent limitations due to factors such as rooftop size and shading, which tend to impact the total energy output. Centralised solar plants, on the other hand, require significant land area and face challenges related to comparatively longer construction timelines and grid integration issues.

The challenges posed by these intermittent renewable energy systems need to be addressed individually, as both options pose an attractive proposition in contributing to decarbonisation efforts. To compare both systems, our analysis for both centralised and decentralised solar generation plants is based on a widely accepted methodology for calculating the *LCOE* [14] and is defined below 0:

$$\text{LCOE} = \sum_{t=1}^{n} \frac{\left(\text{Initial Capex}_t + \text{GCC}_t + \text{OM}_t\right)}{(1+\text{WACC})^{t}} \Big/ \sum_{t=1}^{n} \frac{\text{CF} * 8760}{(1+\text{WACC})^{t}}$$

where t indicates the year of the asset's operation, which ranges between 1 and n (asset's operating life in years). The *Initial capex* indicates the total upfront cost of setting up the power generation plant, including construction and assembly costs. The grid connection costs (*GCC*) are the distance-based costs of spur lines over land and construction-period transit costs. Operation and maintenance expenses (*OM*) cover the annual expenditures to operate and maintain the solar energy generation equipment. *WACC* is the weighted average cost of capital for financing the project assets [15] during the asset's operating life. The Capacity Factor (*CF*) is the ratio of actual annual output to output at rated capacity for an entire year and has been considered as 32% in TAQA's base case estimations. We follow TAQA's lead and adopt this value in our calculations. The numerical value of *8760* represents conversion factor for total available hours per year (24 * 365).

The National Renewable Energy Laboratory (NREL) in their "2024 Electricity Annual Technology Baseline", calculates the *LCOE* (USD/kWh) using equation **Error! Reference source not found.**, where they consider the cost of energy for each year separately, through the project life of the energy producing asset [16].

$$LCOE = ((CRF * PFF * CFF * (OCC * CRM + GCC) + FOM) * 1000/(CF * 8760)) + VOM + Fuel \qquad (2)$$

Where:

- *CRF* = Capital recovery factor - the ratio of a constant annuity to the present value of receiving that annuity for a given length of time;
- *PFF* = Project finance factor - a technology-specific financial multiplier that adjusts for depreciation schedules and tax policy variations;

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- *CFF* = Construction finance factor - the construction period financing share of total capital cost;
- *OCC* = Overnight capital costs - the calculated Capex if the plant was constructed overnight;
- *CRM* = Capital regional multiplier - a multiplier for regional capital cost variation;
- *FOM* = Fixed OM;
- *VOM* = Variable OM; and
- *Fuel* = calculated fuel cost in $/MWh.

We refer to the methodology used by NREL and consider a modified approach of calculating *LCOE,* using a simplified equation 0, which allows us to compare the decentralised and centralised solar systems on an annual basis during the forecast period.

$$LCOE = (CRF * (Initial\ capex + GCC) + OM) * 1000/(CF * 8760)$$

We calculate *CRF* using equation 0.

$$CRF = WACC * (1 / (1 - (1 / (1 + WACC))))$$

In addition to the LCOE, we calculate the *net present value* (NPV) of the total cashflows for each of the plants using equation 0, to ascertain the net benefits arising from the investment incurred:

$$NPV = \sum_{t=1}^{n} \frac{Net\ cashflow_t}{(1 + \mathrm{WACC})^{t}}$$

where *net cashflow* for period *t* is calculated as in equation 0:

$$net\ cashflow = \mathrm{CF} * 8760 * \mathrm{tariff} - \mathrm{capex} - \mathrm{OM}$$

B. Subsidy economics

In Abu Dhabi, the government currently subsidises the use of electricity indirectly. It provides a subsidy to the energy companies, which allows them to keep the customer tariff well below the economic cost, i.e. the total cost of generating, transmitting, and distributing each unit of electricity.

We use Abu Dhabi Department of Energy's (DoE) price control (RC-2) final determinations [37] and TAQA's 2023 financial statements [38] to estimate the impact of these subsidies on the energy sector costs and its customer groups.

In the context of these subsidies, we further evaluate the feasibility of setting up decentralised solar plants by different customer groups, assuming that the set-up cost is borne by the consumer. This feasibility is calculated using the standard financial metrics of internal rate of return (IRR) and payback period on initial investment, while considering the OM expenses and the cost of electricity that is avoided by system's local generation. The costs incurred, namely the initial investment and OM expenses, are considered outflows and we refer to them as outgo, while the costs avoided are considered income in our calculation.

The IRR (*r*) is defined as the rate of discount that makes NPV = 0[39] and is calculated through equation 0:

$$NPV = \sum_{t=1}^{n} \frac{- capex_t + (tariff_t * CF * 8760) - OM_t}{(1 + \mathrm{r})^{t}} = 0$$

The payback period (*y*) is defined as the time in years, between initial outlay of capital to install a solar generation plant and the return on this initial investment [40], considering that income equals the cost of electricity that is avoided by local generation. We calculate the payback period using a modified equation for a simple payback period, to determine *y* in 0, when total outgo is expected to equal the total income:

$$-\sum_{t=1}^{y} (capex_t + OM_t) = \sum_{t=1}^{y} (tariff_t * CF * 8760)$$

Table 1: THE SPECIFICATIONS FOR SYSTEMS CONSIDERED IN CENTRALISED AND DECENTRALISED ENERGY

Specification	**Centralised**	**Decentralised**
Plant size	100 MWdc, 1,500-Vdc	4-3,000 kWdc
Module	530 Wdc bifacial monocrystalline silicon module	410 Wdc monofacial monocrystalline silicon module
Module efficiency	20.50%	20.80%
Inverter	4 MWac utility-scale three-phase central inverter	340 Wac module-scale microinverters
Structural Balance of System (EBOS)	Single-axis tracking installed in-the-field	Parallel to roof mounting includes roof-penetraion mounts, rails, and clamps
Lifespan	25 years	

IV. Data Used

This section discusses the input datasets used in our analysis such as details for the system specifications, cost categories and inputs, and other assumptions.

A. Solar specification data

The solar cells are largely available in three categories: mono crystalline, multi crystalline and thin film PV cells, in decreasing order of efficiency and cost [30].

The specifications for solar systems [31] included in Table 1 have been considered for the calculations presented in this paper.

B. Tariff data

The Abu Dhabi Distribution Company (ADDC), an electricity distribution company in the UAE, charges separate base tariffs to different customer groups, as in Table 6.

We refer to the tariffs presented in Table 2 for our analysis, to estimate the customer level savings, payback period and IRR from installation of a decentralised solar generation system.

Table 2: ADDC 2024 CUSTOMER TARIFFS (AED/kWh) [34]

Customer group	Base tariff
UAE nationals	0.07
Expats	0.27
Industry	0.29
Commercial	0.20
Government customers	0.29
Agriculture	0.05

C. Subsidy data

TAQA, in their annual accounts for 2023, present the consolidated financial statements for their subsidiary companies, including ADDC, Al Ain Distribution Company (AADC) and Abu Dhabi Transmission and Despatch Company (Transco) [38]. We refer to the notes to accounts for the financial data to estimate the total generation, and transmission and distribution (T&D) revenue. Subsequently, we estimate that the power revenue (generation, T&D) is 65% of the total revenue from power and water, while the remaining 35% revenue is from water and allied services.

TAQA also separately indicate 'Other operating revenue', which they calculate as the difference between 'Maximum allowed revenue', as defined in the RC-2 final determinations and the revenue collected from the customers. We refer to this amount as the total 'subsidy' borne by the Abu

Dhabi Government. We further assume that 65% of this total subsidy amount is split in the ratio of 0.75:0.25 between power generation and power T&D, to estimate the total power generation revenue and power T&D revenue.

TAQA annual report states UAE generation of 58,731 GWh (58.7 TWh) is 71% of Abu Dhabi's electricity requirement. Thus, we infer Abu Dhabi's electricity requirement is 82.7 TWh (58.7/ 71%). This also aligns with the Department of Energy price control assumptions for Transco (82,628 GWh for 2023) [37].

We calculate the implied economic cost of electricity to the Government, by separately calculating and adding the power generation tariff and power T&D tariff, using the revenue and electricity volume data.

D. Cost data

The analysis refers to capital expenditure and operating expenditure data for setting up and maintaining centralised and decentralised solar plants, as highlighted in Table 3. We rely on inputs from Falcon Energy, an installer in the UAE, for capex inputs for rooftop and ground-mounted solar plants. Further, we use the published LCOE (US$1.6215 cents/ kWh) for the sixth phase of Mohammed bin Rashid Al Maktoum Solar Park, UAE [33] and derive the indicative capex (AED 1,221/kWh) for a centralised solar plant, shown in Table 3. The bifurcation of capex and opex into the sub-costs is referenced from NREL's cost-breakdown for utility-scale solar [29].

TABLE 3: COST CATEGORIES AND INPUTS CONSIDERED IN OUR COMPARATIVE ANALYSIS AND CALCULATION OF LCOE

Cost categories & inputs (AED 2023)	**Centralised**	**Decentralised**
Capital expenditure	(per kW DC)	(per kW DC)
Module	392	770 - 1,443
Inverter	51	100 - 188
Structural Balance of System (EBOS)	135	265 - 496
Electrical Balance of System (EBOS)	185	363 - 682
Fieldwork	249	489 - 916
Officework	70	137 - 256
Other	141	276 - 518
Total	**1,221**	**2,400 - 4,500**
Operating expenditure	(per kW DC/ year)	(per kW DC/ year)
Cleaning	0.7	5 - 9
Inspection	0.4	3 - 6
New Balance of system (BOS)	0.4	2 - 5
New Modules	0.1	0.5 - 1
New Inverters	0.7	5 - 9
Land Lease	0.6	4 - 8
Insurance	0.8	6 - 11
Management	0.5	3 - 6
Other	0.6	4 - 7
Total	**4.8**	**32 - 61**

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E. Other assumptions

In 2024, Abu Dhabi is estimated to have over 3.1 GW of rooftop solar potential with over 17.8 thousand rooftops in the commercial and industrial sectors [41].

The construction period is assumed to be 3 months for residential, 6 months for non-residential customers and 1 year for setting up the decentralised solar generation of 292 MW, in Abu Dhabi in our base adoption scenario.

UAE CPI of 2% is assumed for cashflows starting 2025 for forecasting tariff and costs. We rely on International Renewable Energy Agency's (IRENA) estimate of 464 tonnes of CO2 emissions in UAE per GWh of electricity generation [36].

The capex assumptions for a centralised solar plant excludes grid connection costs, transmission and distribution costs, and financing costs.

In Abu Dhabi, the Small-scale Solar PV Energy Netting Regulation was issued in 2017 [35]. Our analysis assumes that the benefit to the customer for each unit of electricity generated from decentralised solar equals the retail value (i.e. "Net metering" - the owners are paid the same price for electricity they sell to the grid as electricity they buy from the grid).

We use IEA estimates for the UAE, to bifurcate the electricity consumption in Abu Dhabi by different customer groups, as shown in Table 4 below.

Table 4: UAE electricity consumption by customer group-2022 [42]

Customer group	Proportion
Residential	29.6%
Industry	16.5%
Commercial and public services	50.0%
Agriculture/ forestry	2.6%
Not specified	1.3%

V. Results and Discussion

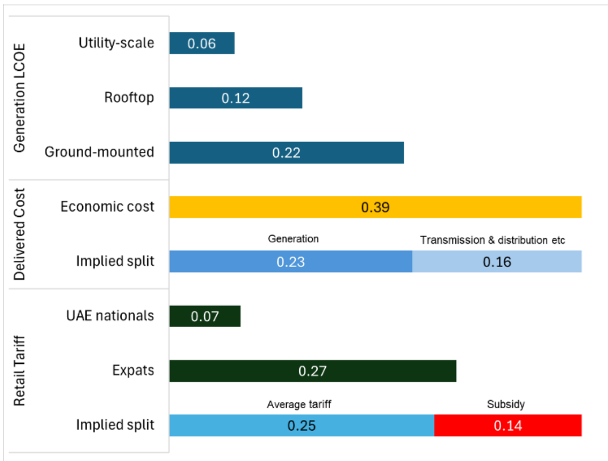
The specific impact of decentralised and centralised solar systems, especially on grid-stability, can vary depending on factors such as grid size, solar penetration levels, and the presence of other renewable energy sources (such as wind, hydro). It is important to consider these factors when evaluating the potential benefits and challenges of different solar energy deployment strategies.

A. Economic viability

According to our analysis of Abu Dhabi Department of Energy's price control (RC-2) final determinations and TAQA's 2023 financial statements, the average economic cost for electricity lies in the range of 36-41 fils/ kWh (0.36-0.41 AED/kWh).

Until recently, rooftop solar was not viable in Abu Dhabi [6], as the costs were too high. However, that is not the case anymore. Since 2016, the costs have materially reduced and fallen below both the economic cost and the tariff charge levels.

Figure 5: MCC analysis of LCOE for solar energy projects and comparison with Economic cost of electricity and tariffs (AED/kWh)



We estimate that rooftop solar is very cheap, at 12 fils/kWh, compared to the economic cost of electricity of 39 fils/kWh and to the expats tariff of 27 fils/kWh. However, it is not cheap enough for UAE nationals on the heavily subsidised retail tariff (7 fils/kwh) or for agricultural customers (5 fils/kwh) as shown in Figure 5.

Ground-mounted solar, at 22 fils/kwh, is not as attractive to customers on the expat tariff of 27 fils/kWh or commercial tariff of 30 fils/kwh, but it is still worthwhile for the Government, because its significantly cheaper than the economic cost of 39 fils/kwh.

B. Possible savings

For each customer group in Abu Dhabi, we estimate costs and savings for both rooftop and ground-mounted solar systems. We modelled these and estimated the returns on investment (IRR) and payback periods. The results from our analysis are shown in Table 6.

Our analysis of distributed solar generation projects based on current cost data indicates that rooftop and ground-mounted solar systems can deliver electricity with LCOEs in the range of 11 fils/kWh (rooftop, residential) to 22 fils/kWh (ground-mounted, industry). Notably, the difference in returns and payback analysis is largely due to the subsidy effect, as our analysis indicates that the payback period and IRR from the customers' perspective have little correlation to LCOE, especially in the UAE national's case.

If there was no subsidy from the UAE government, the overall benefits would be larger. Since the IRR for UAE nationals is low (0.2% - 1.4%), there is a large benefit to the UAE government from the adoption of decentralised solar energy, as the subsidy would be reduced by the largest amount, 0.32 AED/kwh, to the UAE nationals, as shown in Figure 5. This large decrease would also occur for customers in the agriculture sector.

C. Impact on subsidy

We consider three adoption scenarios, for decentralised solar starting 2025 in Abu Dhabi - 0.5%, 1.0% and 1.5%, of total electricity required.

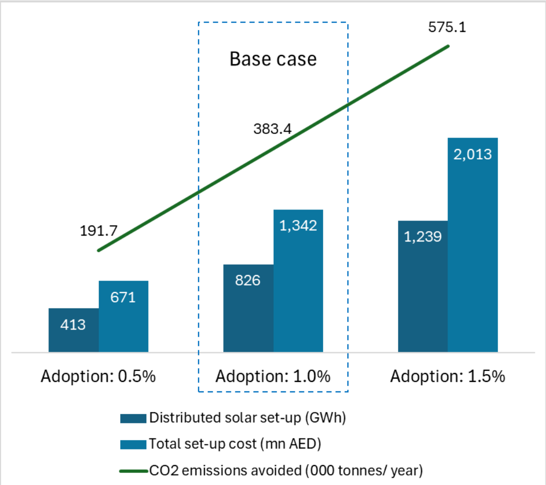
In the base case, we estimate that the total set-up cost to generate 1% of Abu Dhabi's electricity requirement is AED 1,342 million, with an estimated annual electricity generation of 826 GWh. We further estimate an annual reduction in subsidy borne by the Government will be AED 112.1 million, in a situation that is simultaneously beneficial for the government, customers and the environment.

Table 5: MCC analysis of Distributed solar generation - customer groups, respective tariff, size, costs, payback period and IRR

Customer group	Residential: UAE national	Residential: Expat	Commercial	Industry
Base tariff (AED/ kWh)	0.07	0.27	0.20	0.29
Distributed system type	Rooftop	Rooftop	Rooftop	Ground-mounted
Size (kW)	4	4	500	900 - 3,000
Set-up cost ('000 AED)	9.8 - 10.6	9.8 - 10.6	1,224 - 1,326	3,213 - 13,770
Maintenance cost: Year 1 ('000 AED)	0.1	0.1	17 - 18	44 - 187
LCOE	0.11 - 0.12	0.11 - 0.12	0.12 - 0.13	0.17 - 0.22
Payback period (years)	17.6 - 22.8	3.2 - 3.5	4.4 - 4.8	4.5 - 5.9
IRR (25 years)	0.2% - 1.4%	30.8% - 34.0%	20.8% - 23.0%	16.1% - 22.4%

For each adoption scenario, we calculate the total set-up cost, total electricity generated, and carbon emissions avoided. The outputs are summarised in Figure 6.

Figure 6: MCC analysis for three adoption scenarios, distributed solar size, set-up cost and CO2 emissions avoided

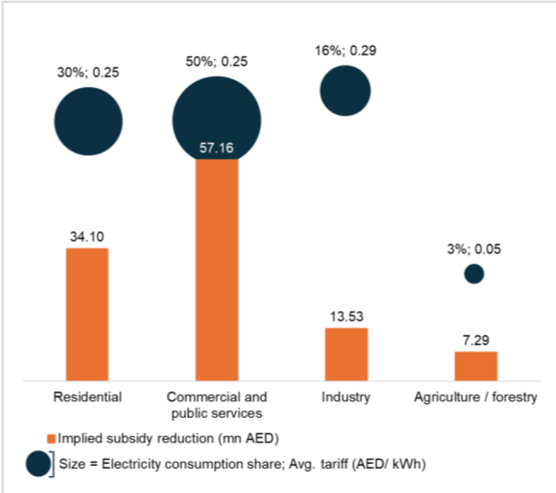


To decarbonise and achieve net zero, one of the key steps highlighted in the National Climate Change Plan includes a subsidy reform [9]. As part of this, revision in tariff structures shall be undertaken by the water and electricity authorities throughout the country, with an aim to cut subsidies to customers and increase prices gradually.

The current electricity tariffs, especially for the local citizens of UAE, discourage the deployment of distributed solar technology. [22] However our analysis shows that the economics are attractive for all electricity customers, except those on the "local citizen tariff".

We show the breakdown of the implied annual reduction in subsidy for the base case, by customer group in Figure 7.

Figure 7: Abu Dhabi tariff vs implied subsidy reduction in Base case for distributed solar (by customer group)



D. Environmental benefits

Taking Abu Dhabi as an example, we have shown, in this paper, how subsidies may impede net zero

TABLE 6: MCC ANALYSIS OF DISTRIBUTED SOLAR ADOPTION SCENARIOS AND COMPARISON WITH CENTRALISED SOLAR APPROACH

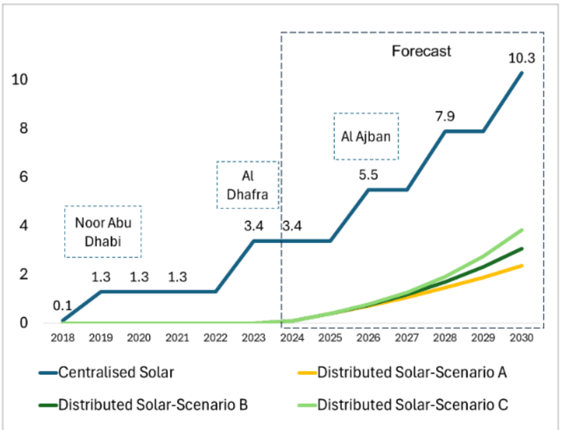
Type	**Distributed Solar Generation Scenarios**			**Centralised Solar**
Adoption scenario	**A**	**B**	**C**	**Baseline**
Capacity in 2024 (GW)	< 0.1	< 0.1	< 0.1	3.4
Incremental annual growth in capacity from 2024 (%)	10%	21%	30%	20%
Capacity by 2030 (GW)	2.4	3.1	3.8	10.3
Total set-up cost - real (bn AED)	5.4-10.2	7.1-13.3	9.0-16.8	8.41
Annual generation in 2030 (GWh)	6,658	8,659	10,823	29,073
Subsidy reduction in 2030 - real (Mn AED)	903	1,175	1,468	3,943
CO2 emissions avoided in 2030 (million tonnes/ year)	3.1	4.0	5.0	13.5

targets. By paying for everyone's electricity costs, the government displays its generosity, but under certain circumstances subsidies can be self-defeating and bad for climate change. Clean-energy investments likely are a better use of subsidy monies - potentially simultaneously benefiting the government, customers and the environment.

In the base case scenario for setting up distributed solar energy generation in Abu Dhabi, we estimate that 292 MW of generation capacity would be set up during 2025, to supply 1% of total electricity requirement. Subsequently, we model three different scenarios - A, B and C, for different growth rates in incremental annual capacity, i.e. 10%, 21% and 30%. As per scenario C, we expect the total annual generation from distributed solar to be 10.8 TWh, which would supply approximately 10% of the estimated electricity demand, so it seems fairly reasonable. The results from our analysis are presented in TABLE 7.

We further model the capacity increase in centralised solar generation in Abu Dhabi, with an estimated capacity of 10.3 GW by 2030. Based on the data available, planned projects by TAQA and our forecast assumptions, we display the historical and forecasted solar generation capacity between 2018 to 2030, in Figure 8.

Figure 8: Historical and forecasted capacity - Centralised vs distributed solar (GW)



In scenario C, the investment in distributed solar would translate into a reduction of annual subsidy by AED 1.47 billion (real, 2024 prices) and an annual reduction of 5 million tonnes of carbon emissions in 2030.

VI. Conclusions

The potential for distributed solar generation offers a promising avenue for local private sector engagement in Abu Dhabi's expanding clean energy landscape. Abu Dhabi can enhance its strategic energy options, boost the local economy and clearly demonstrate its commitment to sustainability.

The net metering scheme in Abu Dhabi was not found to be an economic or technical barrier [35] to this implementation. Distributed solar generation is cheap enough to benefit the UAE government (and the economy) in all our scenarios/customer groups. However, distributed solar is not cheap enough to be attractive to customers who receive the largest government subsidies, namely UAE nationals and agricultural customers. Our analysis also shows that the economics of distributed solar are very attractive, given the average payback period of only 5 years as show in Table 6 above.

Future research should be directed at the potential reasons for the slow update of decentralised solar generation in Abu Dhabi, such as:

1. costs for setting up distributed solar generation are not economically viable until quite recently, for most consumers.

2. lack of space for a large enough rooftop system to meet the daily energy requirements.

3. skepticism regarding the success of distributed generation over a long-term use.

4. the short-term nature of residence for expats and near-term planning of businesses.

5. legal barriers to implementation (e.g. DoE determination [43]);

6. subsidised tartariffs.

7. asset strstranding. displacement effects; and

https://doi.org/10.54878/7ch8vc22

9. issues with grid management and tariff pricing (e.g. negative prices, access charges).

Further research is also needed to explore several critical dimensions of decentralised solar generation in Abu Dhabi. First, the optimal level of distributed generation for Abu Dhabi, considering factors such as grid stability, energy demand, and cost efficiency, remains an open question. Policymakers, particularly within the Department of Energy Abu Dhabi, should examine tailored policy options to incentivize solar adoption in buildings while ensuring grid reliability and long-term sustainability.

Additionally, the impact of battery storage systems on the efficiency and reliability of distributed solar needs further investigation [28], particularly in relation to technological advancements and their indirect costs.

Furthermore, the sale of carbon credits from decentralised solar projects and the integration of demand response planning, net metering policies, and electric vehicles (EV) storage present other opportunities for deeper research.

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