

Rooftop Solar Framework for New Residential Housing Developments in Saudi Arabia

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Research Article

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Abstract

Saudi Arabia possesses a great deal of solar energy potential, yet the adoption of decentralized PV systems remains low in the kingdom. Low electricity tariffs, high upfront capital costs, and other constraints have all been causes of low residential PV adoption among homeowners.

This study examines how a mandatory rooftop-PV requirement for new villa developments could be designed to expand distributed solar generation in Saudi Arabia while balancing the financial interests of developers, benefits to residents, and the development of a domestic renewable-energy market. Rather than relying on individual homeowners to install PV systems, this study recommends that new villa developments install PV systems during construction. This avoids the need for separate homeowner adoption decisions, which tends to be less financially attractive for the individual homeowner.

This study uses four different Saudi residential-PV studies for each one of the three key parameters: PV capacity, PV yield, and Installation costs. In a hypothetical scenario where 10,000 villas are planned for construction in a given neighborhood under the policy design, PV capacity is 120 MWp, annual generation is 216,000,000 kWh/year = 216 GWh/year, and total installed cost is SAR 480 million. The simple tariff-equivalent payback would be roughly 12.4 years. As a result, approximately 122,700 tonnes of CO₂ emissions could be avoided annually if the full 216 GWh of annual PV generation displaced grid electricity at the Saudi emission factor.

The framework could potentially create an aggregated and predictable PV market for PV manufacturers, electrical contractors and engineering firms, while creating conditions conducive to greater private-sector participation.

1. Introduction

Saudi Arabia ranks sixth globally for solar energy potential worldwide [1], yet adoption of decentralized PV panels remains low in residential households. Low electricity tariffs, high upfront capital costs, and cultural and technical constraints have all been identified as contributing factors to low PV adoption [2]. However, if PV adoption becomes commonplace, it could help the kingdom achieve the 50% renewable generation plan under Vision 2030 [3].

Vision 2030 has mostly focused on large-scale generation, while residential distributed PV remains comparatively underdeveloped [4]. Retrofitting PV is both difficult and costly; therefore, new construction can pose a lucrative intervention point. However, mandatory PV installation can create high costs for developers, so intentional policy design is crucial.

This study examines how a mandatory minimum rooftop PV requirement for new villa developments could be designed to expand distributed solar generation in Saudi Arabia while balancing the financial interests of developers, benefits to residents, public-sector objectives, and the development of a domestic renewable-energy market.

2. Proposed Policy Framework

1) All new villa developments are required to incorporate rooftop PV during construction.

Rather than relying on individual homeowners to install PV systems, this study recommends that new villa developments install PV systems during construction. This avoids the need for separate homeowner adoption decisions, which tend to be costlier and generally less financially attractive for the individual homeowner.

The actual regulatory requirement for the size of a PV system should be determined by the size of the rooftop and the building's characteristics; therefore, the 12 kWp figure used later is only an assumption and not necessarily the mandated capacity for every future home, though it is a useful estimation.

2) Financing and Cost Allocation Strategy.

Installation costs should become part of the overall construction cost instead of a separate purchase for the homeowner; therefore, a portion of the costs can be incorporated into the final housing pricing.

Government-backed financing could potentially assist developers facing capital constraints. This is in order to avoid developers absorbing the entire PV costs, which could create cash flow problems, especially for smaller developers.

Requiring the government to subsidize a fixed percentage would be arbitrary, so the policy should rather facilitate access to financing and not prescribe a universal subsidy.

Developers should be able to procure PV systems through standardized bulk contracts, since purchasing large numbers of PV can simultaneously reduce transaction costs and potentially capture economies of scale, while also standardizing maintenance.

3) Maintenance.

Since PV systems can experience degradation, soiling, and other faults over their lifetimes, maintenance should be within the contractors/service providers' responsibility and can be a part of the installation contract.

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3. Methodology and Scenario Design

This study uses at least three different Saudi residential-PV for each one of the three key parameters: PV capacity, PV yield, and Installation costs. These parameters are averaged out and chosen based on

existing literature since this study has no direct access to any PV systems for a rooftop PV test. Under the current system, these are the following numbers:

Avg. PV capacity: 12 kWp per villa

Source	PV capacity
[2] Alshehri, James & Bahaj (2024)	9–10 kWp
[5] Alghamdi et al. (2023)	8–12 kWp
[6] Imam, Al-Turki & Kumar (2020)	12.25 kWp
[7] Alghamdi et al. (2025)	15.12 kWp

Avg. PV yield: 1,800 kWh/kWp/year

Source	PV yield
[8] Almasri, Alardhi & Dilshad (2021)	1,649 kWh/kWp/year
[9] Almushaikah & Almasri (2021)	1,890.9 kWh/kWp/year
[10] Almarshoud (2017)	2,024.7 kWh/kWp/year

Avg. installed costs: SAR 4,000/kWp

Source	Installed PV cost
[11] Dehwah et al. (2020)	SAR 4,500/kWp
[7] Alghamdi et al. (2025)	SAR 4,688/kWp
[12] Alaboodi & Alharbi (2024)	SAR 3,800/kWp
[13] Zubair (2024)	SAR 2,813/kWp

In a hypothetical scenario where 10,000 villas are planned for construction in a given neighborhood under the policy design, we get the following numbers:

Per villa:

Annual generation: $12 \times 1,800 = 21,600$ kWh/year

Installed cost: $12 \times 4,000 = \text{SAR } 48,000$

Under the 10,000 villa scenario:

PV capacity: $10,000 \times 12 = 120$ MWp

Annual generation: $10,000 \times 21,600 = 216,000,000 \text{ kWh/year} = 216 \text{ GWh/year}$

Total installed cost: $10,000 \times 48,000 = \text{SAR } 480 \text{ million}$

4. Results and Discussion

1) Electricity generation.

What does 216 GWh/year actually look like in practice?

The GASTAT reports that the kingdom had 6,551 MW of operational renewable capacity at the end of 2024 [14]. Within this 10,000-villa scenario, this represents roughly 2% of Saudi Arabia's 2024 operational capacity. This shows that the scenario is not necessarily nationally transformative by itself; however, it demonstrates that it only took 10,000 villas to theoretically add a measurable amount of solar capacity.

PV exports

Alshehri et al. report that Saudi residential electricity demand is heavily AC-driven, with 70% of the residential-sector demand being attributed to AC. More importantly, they also found that only 2.7% of PV electricity is exported. This hints at the fact that Saudi PV can have a high degree of self-consumption, because PV production overlaps with daytime cooling hours and demand. This also supports the later SAR 0.18/kWh figure, as most electricity is being consumed and not exported.

Energy security

This decentralized method of electricity generation diversifies the locations from which electricity is supplied and reduces dependence on grid-supplied electricity (During times of PV production).

2) Economic Results.

How long would it take for the avoided electricity expenditure to equate to the SAR 480 million in total costs? Saudi Arabia's current residential tariff is SAR 0.18/kWh. At SAR 0.18/kWh:

$$216,000,000 \times 0.18 = \text{SAR } 38.88 \text{ million/year}$$

The simple tariff-equivalent payback would be roughly 12.4 years ($480 / 38.88 = 12.35 \text{ years}$), which would be the approximate time required for the electricity expenditure avoided under the SAR 0.18/kWh assumption to equal the initial total costs. This number should also be understood as a tariff-equivalent benchmark and not a forecast of the financial recovery.

As already discussed, bulk procurement with thousands of household purchases can also reduce the transaction costs and therefore the total costs, so the tariff-equivalent payback time may actually be lower than the current calculation.

3) Environmental implications

Saudi's grid-emission factor is 0.568 kg CO₂/kWh [15].

This scenario generates approximately 122,688,000 kg CO₂/year under:

$$216,000,000 \times 0.568 = 122,688,000 \text{ kg CO}_2/\text{year}$$

Therefore, approximately 122,700 tonnes of CO₂ emissions could be avoided annually if the full 216 GWh of annual PV generation displaced grid electricity at the Saudi emission factor.

4) Market, Employment and Investment

A predictable PV market

Under regular conditions, PV adoption depends on thousands of individual homeowners independently deciding to consider solar, find an installer, finance the system, and arrange installation; however, under this policy, the PV demand is embedded into the construction itself. This means that there will be an aggregated and predictable PV market for PV manufacturers, electrical contractors, and engineering firms.

PV localization

If developers repeatedly procure systems at scale, firms will have an incentive to develop capacity for the Saudi residential market. Domestic manufacturing/localization can potentially take place if economically viable.

Employment

During the construction phase of the policy, a short-term increase in demand for installation and electrical labor will occur, effectively creating new short-term jobs; however, during the operational phase, continued demand for maintenance, monitoring, and troubleshooting will be needed, therefore creating long-term jobs.

Investment

The framework could create conditions that may be attractive to private companies, due to customer acquisition being less fragmented and project volumes being easier to forecast. However, this paper is not claiming that investment is guaranteed; rather, the framework can potentially create conditions conducive to greater private-sector participation.

5) Limitations

No household testing

We can estimate how much PV energy is generated, but we do not know exactly how much electricity each villa consumes; therefore, calculating exact self-consumption, exports, and grid imports avoided becomes impossible.

Representative inputs and results

All parameters are derived from existing literature and implemented in a hypothetical scenario and are not actually measured from 10,000 villas. The results can only demonstrate the potential scale of the framework. The simple tariff-equivalent payback calculation also does not include financing costs, maintenance, degradation, tariff changes, export compensation, or discount rates. The CO₂ estimate also depends on how much PV displaces grid electricity.

5. Conclusion

Saudi Arabia possesses a great deal of solar energy potential, yet the adoption of decentralized PV systems remains low in the kingdom. Low electricity tariffs, high upfront capital costs, and other constraints have all been causes of low residential PV adoption among homeowners.

This study examines how a mandatory rooftop-PV requirement for new villa developments could be designed to expand distributed solar generation in Saudi Arabia while balancing the financial interests of developers, benefits to residents, and the development of a domestic renewable-energy market. Rather than relying on individual homeowners to install PV systems, this study recommends that new villa developments install PV systems during construction. This avoids the need for separate homeowner adoption decisions, which tends to be less financially attractive for the individual homeowner.

In a hypothetical scenario where 10,000 villas are planned for construction in a given neighborhood, under the policy design, we get the following numbers:

Annual generation: $12 \times 1,800 = 21,600$ kWh/year.

Installed cost: $12 \times 4,000 = \text{SAR } 48,000$.

Under the 10,000 villa scenario,

PV capacity: $10,000 \times 12 = 120$ MWp.

Annual generation: $10,000 \times 21,600 = 216,000,000$ kWh/year = 216 GWh/year.

Total installed cost: $10,000 \times 48,000 = \text{SAR } 480$ million.

The GASTAT reports that the kingdom had 6,551 MW of operational renewable capacity at the end of 2024. Within this 10,000-villa scenario, this represents roughly 2% of Saudi Arabia's 2024 operational

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Saudi Arabia's current residential tariff is SAR 0.18/kWh.

At SAR 0.18/kWh,

$$216,000,000 \times 0.18 = \text{SAR } 38.88 \text{ million/year.}$$

The simple tariff-equivalent payback would be roughly 12.4 years, which would be the approximate time required for the electricity expenditure avoided under the SAR 0.18/kWh assumption to equal the initial total costs. This number should also be understood as a tariff-equivalent benchmark and not a forecast of the financial recovery.

This scenario approximately avoids 122,688,000 kg CO₂/year under:

$$216,000,000 \times 0.568 = 122,688,000 \text{ kg CO}_2/\text{year.}$$

Therefore, approximately 122,700 tonnes of CO₂ emissions could be avoided annually if the full 216 GWh of annual PV generation displaced grid electricity at the Saudi emission factor.

Saudi PV can have a high degree of self-consumption because PV production overlaps with daytime cooling hours and demand. This also supports the SAR 0.18/kWh figure, as most electricity is being consumed and not exported.

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References

1. Albraheem L, Alabdulkarim L (2021) Geospatial analysis of solar energy in Riyadh using a GIS-AHP-based technique. *ISPRS Int J Geo-Information* 10(5) Article 291. <https://doi.org/10.3390/ijgi10050291>
2. Alshehri A, James PAB, Bahaj AS (2024) Pathways to the large-scale adoption of residential photovoltaics in Saudi Arabia. *Energies* 17(13) Article 3180. <https://doi.org/10.3390/en17133180>
3. Ministry of Energy (n.d.). *National Renewable Energy Program (NREP)*. Government of Saudi Arabia. <https://www.moenergy.gov.sa/en/eco-system/programs/renewable-energy>
4. Elshurafa AM, Hasanov FJ, Hunt LC (2024) Macroeconomic, energy, and emission effects of solar PV deployment at utility and distributed scales in Saudi Arabia. *Energy Strategy Reviews* 53:101423. <https://doi.org/10.1016/j.esr.2024.101423>
5. Alghamdi A, Alam M, Blunden L, Bahaj AS, Aragon V, James PAB (2023) A combined monitoring and modelling approach to understand cooling loads for residential PV system sizing: Case study of a villa in Jeddah. *Proceedings of the International Conference on Evolving Cities*, 51–54. <https://doi.org/10.55066/proc-icec.2022.92>
6. Imam AA, Al-Turki YA, Kumar SR (2020) Techno-economic feasibility assessment of grid-connected PV systems for residential buildings in Saudi Arabia—A case study. *Sustainability* 12(1). <https://doi.org/10.3390/su12010262>. Article 262
7. Alghamdi A, Blunden LS, Alam M, Bahaj AS, James PAB (2025) Evaluating the opportunities and challenges of domestic PV installation in Saudi Arabia based on field deployment in Jeddah. *Energies* 18(11). Article 2733. <https://doi.org/10.3390/en18112733>
8. Almasri RA, Alardhi AA, Dilshad S (2021) Investigating the impact of integration the Saudi Code of Energy Conservation with the solar PV systems in residential buildings. *Sustainability* 13(6):3384. <https://doi.org/10.3390/su13063384>
9. Almushaikah AS, Almasri RA (2021) Evaluating the potential energy savings of residential buildings and utilizing solar energy in the middle region of Saudi Arabia—Case study. *Energy Explor Exploit* 39(5):1457–1490. <https://doi.org/10.1177/0144598720975144>

10. Almarshoud AF (2017) Technical and economic performance of 1MW grid-connected PV system in Saudi Arabia. *Int J Eng Res Appl* 7(4):09–17. <https://doi.org/10.9790/9622-0704010917>
11. Dehwah AHA, Asif M, Budaiwi IM, Alshibani A (2020) Techno-economic assessment of rooftop PV systems in residential buildings in hot-humid climates. *Sustainability* 12(23):10060. <https://doi.org/10.3390/su122310060>
12. Alaboodi AS, Alharbi SJ (2024) A study on the techno-economics feasibility of a 19.38 kWp rooftop solar photovoltaic system at Al-Abrar Mosque, Saudi Arabia. *Energies* 17(10). <https://doi.org/10.3390/en17102325>. Article 2325
13. Zubair M (2024) PV energy penetration in Saudi Arabia: Current status, residential, and commercial users, local investment, use in modern agriculture. *Int J Sustain Eng* 17(1):39–51. <https://doi.org/10.1080/19397038.2023.2297262>
14. General Authority for Statistics (2025) *Renewable Energy Statistics 2024*. Government of Saudi Arabia. <https://www.stats.gov.sa/documents/d/guest/renewable-energy-statistics-2024-en-1-pdf>
15. Red Sea Global (2024) RSG Sustainability Report 2023. Red Sea Global. <https://www.tendancehotellerie.fr/IMG/pdf/sustainabilityreport-29thaug.pdf>