THE POLICY INITIATIVE

Stand Out of Our Light: Loss of photovoltaic infrastructure from Israel's war on Lebanon from 2023 onward

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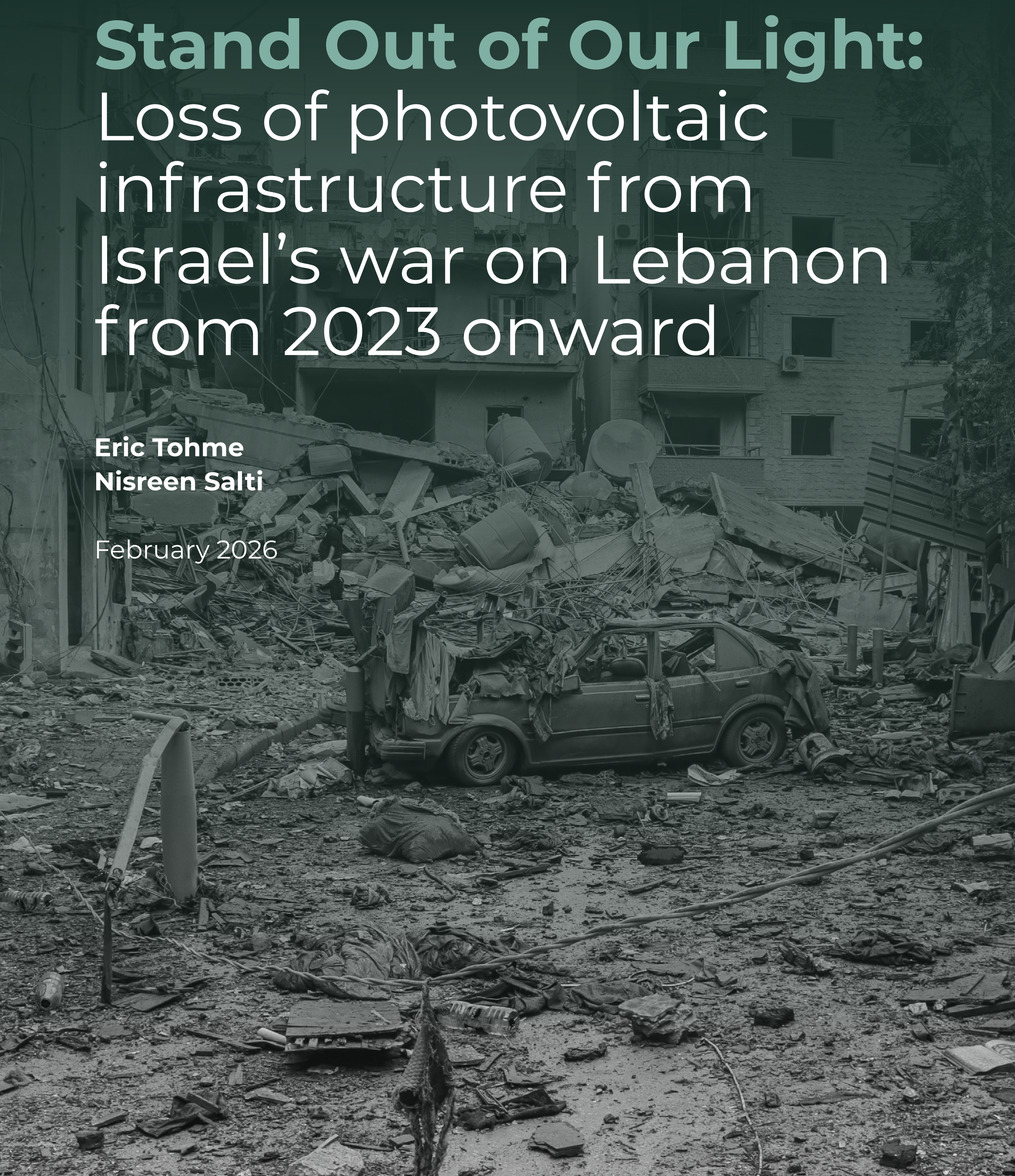
February 2026



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Eric Tohme is a final-year student at Sevenoaks School in the UK, where he is completing the International Baccalaureate Diploma. His academic interests centre on development economics and the "energy trilemma": balancing energy security, equity, and sustainability. He has undertaken internships in both Lebanon and the United Kingdom with organisations including Shell, TowerBrook, and Banque Audi, gaining exposure to the intersection of finance, energy, and development.

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Introduction

Between October 8, 2023, and the ceasefire signed on November 27, 2024, the death toll from Israeli strikes in Lebanon is estimated at close to 4,000 people, though some estimates put the number of fallen at up to 5,000.[1][2][3] However, Israel's armed aggression did not end at the time of the ceasefire, with artillery fire and airstrikes ongoing at the time of writing. The resulting human and material costs are immense. An initial assessment of the damage was summarized in a report by the National Council for Scientific Research,[4] which estimated that the destruction of buildings in the southern suburbs of Beirut resulted in nearly four million tons of rubble, in addition to significant losses of critical infrastructure and agricultural production.

Yet one critical dimension of the war's toll remains far less visible in public debate: the environmental setback caused by the destruction of photovoltaic (PV) infrastructure, and the resulting rise in greenhouse gas (GHG) emissions as households, farms, and businesses are pushed back toward diesel-based electricity. As Lebanon's public electricity system collapsed in recent years, solar power emerged as one of the most viable (and in many cases, the only) alternative energy sources for households, businesses, and farms.[5] The conflict did not just destroy this infrastructure; it abruptly reversed years of organic transition toward clean energy. Thousands of people were left more reliant, again, on diesel generators and fossil fuels, directly increasing carbon emissions and environmental degradation.[6] Moreover, the resulting internal migration of populations from the border towns and villages of South Lebanon into cities located further north led to increased pressure on the infrastructure of those destination cities. This pressure meant an inevitably increased reliance on diesel generators necessary to cope with their consumption, and the associated elevated emissions. Finally, in the absence of any government-led reconstruction or rehabilitation plan, the trajectory of the pre-conflict energy sector has not only been interrupted but also actively reversed. Investment in solar energy to replace the destroyed infrastructure will likely remain minimal as long as the risk of aggression continues.[7]

This paper documents an overlooked environmental cost of Israel's 2023–2024 war on Lebanon: the destruction—and stalled expansion—of the country's rapidly growing solar, or photovoltaic (PV), infrastructure, and the emissions rebound that follows when communities fall back on diesel generation. We focus on losses across residential, commercial, industrial, and agricultural systems, arguing that the conflict did not just

1. Human Rights Watch. 2025. World Report 2025: Lebanon. Human Rights Watch. Available at: https://www.hrw.org/world-report/2025/country-chapters/lebanon

2. Al Jazeera. 2025. "How many people has Israel killed in Lebanon since the ceasefire?" Available at: https://www.aljazeera.com/news/2025/1/28/how-many-people-has-israel-killed-in-lebanon-since-the-ceasefire

3. Reuters. 2025. "Can Lebanon disarm Hezbollah?" Available at: https://www.reuters.com/world/middle-east/can-lebanon-disarm-hezbollah-2025-08-06/

4. National Council for Scientific Research and National Center for Natural Hazards and Early Warning. 2024. "Israeli Offensive on Lebanon 2023-24: Overview of attacks and damages across key sectors." Available at: https://ewsp.gov.lb/wp-content/uploads/2024/12/CNRS-L-War-Report-2023-2024-English.pdf

5. Arab Reform Initiative. 2025. "Rebuilding Lebanon: Clean Energy Access and Challenges." Available at: https://www.arab-reform.net/publication/rebuilding-lebanon-clean-energy-access-and-challenges/

6. Low Carbon Power. 2023. "Lebanon." Available at: https://lowcarbonpower.org/region/Lebanon

7. UN Economic and Social Commission for Western Asia & UNDP. 2025. The Socioeconomic Impacts of the 2024 War on Lebanon. Available at: https://www.undp.org/sites/g/files/zskgke326/files/2025-07/report_socioeconomic-impacts-lebanon-2024-war-english.pdf

damage solar panels; it interrupted and reversed a bottom-up clean-energy transition that had emerged as a substitute for the collapsing public electricity system.

Our core finding is a double loss: panels destroyed and panels never imported due to conflict risk. Based on reported destruction of roughly 400,000–500,000 solar panels (about 150–200 MW), the resulting replacement with Lebanon’s prevailing mix of private generator and the public grid implies sizeable additional annual CO_2 emissions. Once we also account for the 2024 import shortfall, the estimated excess rises further, producing a meaningful reversal of Lebanon’s recent solar gains. Combined, the total rebound reaches roughly 511,595–613,284 tCO_2 extra emissions per year, which corresponds to about US$25.6–30.7 million annually using a conservative US$50/$tCO_2$ benchmark—and would be substantially higher under more expansive social-cost valuations that incorporate wider climate damages.

Following the introduction, the paper maps the three main uses of solar energy in Lebanon and the implications of their losses. It then traces the pre-war surge in decentralized solar energy through import and capacity trends, with brief benchmarking. Next, it presents the emissions estimates alongside scaling and monetized cost calculations. The discussion then turns to robustness checks and longer-term risks, including agricultural disruption and rising e-waste. The paper closes with the implications for recovery and priorities for rebuilding energy resilience.

Three Distinct Uses, One Shared Loss

Although data separated by type is scarce, solar energy in Lebanon can be broadly categorized into three primary uses:[8]

◊ Residential systems, usually rooftop setups with battery storage, were adopted out of necessity by households seeking energy security amid state failure. These systems played a major role in reducing reliance on privately run diesel generators and cutting emissions at the neighborhood level.[9] The economic collapse, which started in late 2019, and the ensuing fuel crisis in 2020, heralded a period of rapid rooftop PV system installation. By the end of 2022, Lebanon had installed approximately 690 MW of cumulative PV capacity, up from 90 MW in 2020, which constitutes a whopping 667% increase in just two years.[10] In 2023, this rapid growth continued as the share of small-scale residential PVs in newly installed capacity surged from 8.56% in 2022 to 18.15%.[11]

◊ Industrial and commercial systems are usually large systems with some type of storage, which can support factories, workshops, and commercial buildings. These systems, when damaged, usually stop operations and cause a fallback to less environmentally friendly backup power.

◊ Agricultural solar systems are typically small, consisting of off-grid panels that power irrigation pumps. These systems have little to no energy storage capacity, but are essential to local food production. Their loss directly interrupted irrigation cycles and damaged crops, increasing dependence on diesel-fueled pumps. For agricultural communities especially, this impact is layered on top of additional environmental losses such as burned orchards, scorched fields, degraded soils from phosphorus bombs, and the destruction of greenhouses.[12]

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8. Arab Reform Initiative. 2025. "Rebuilding Lebanon: Clean Energy Access and Challenges" Available at: https://www.arab-reform.net/publication/rebuilding-lebanon-clean-energy-access-and-challenges/

9. Low Carbon Power. 2023. "Lebanon." Available at: https://lowcarbonpower.org/region/Lebanon

10. PVknowhow.com. 2025. Available at: https://www.pvknowhow.com/news/lebanon-solar-investment-panel-imports-500-million/

11. Climatescope. 2024. "Lebanon Market Profile." Available at: https://www.global-climatescope.org/markets/lebanon

12. UNDP. 2023. "Preliminary Findings on the Socio-Economic and Environmental Impact on Lebanon." Available at: https://www.undp.org/lebanon/press-releases/undp-report-lebanon-faces-potentially-dire-socio-economic-and-environmental-impacts-gaza-war

Crisis-Accelerated Growth in Solar Energy

Between 2019 and 2023, Lebanon saw a massive surge in decentralized solar installations. In 2022, more than 80,000 tons of solar panels were imported, and private spending on them exceeded $500 million, which amounts to close to 2.5% of the GDP.[13] By mid-2023, Lebanon managed to achieve a total of 1,005 MW of installed capacity, with the vast majority being residential and unregulated.[14] This is equivalent to around 30% of the country's total installed electricity production of close to 3,500 MW.[15]

Table 1 scales Lebanon's pre-war progress on solar energy capacity to its demographic, geographical, and economic size. It also uses Cyprus and Jordan as points of comparison since they have similar sun exposure, and all three countries are net fuel importers. While Cyprus appears to boast the highest capacity per capita by far, Lebanon shows a higher density of solar panels and more solar capacity per dollar of GDP than either Jordan or Cyprus.

13. PVknowhow.com. 2025. Available at: https://www.pvknowhow.com/news/lebanon-solar-investment-panel-imports-500-million/

14. PVknowhow. 2025. "Lebanon Solar Panel Manufacturing | Market Insights Report." Available at: https://www.pvknowhow.com/solar-report/lebanon/

15. IEA. 2025. "Lebanon - Electricity." International Energy Agency. Available at: https://www.iea.org/countries/lebanon/electricity

Table 1: Lebanon solar capacity compared to neighboring countries

Country	Installed solar capacity (MW)	Solar capacity per capita (MW/million people)	Solar capacity per area basis (MW/1000km²)	Solar capacity relative to GDP (MW/billion USD)
Lebanon	1,005[16]	174[17]	98.2[18]	50.05[19]
Cyprus	797[20]	582[21]	86.2[22]	33.7[23]
Jordan	1,800[24]	156[25]	20.3[26]	21.8[27]

The World Energy Council noted that solar adoption was driven not by public policy but by necessity, as households and businesses were forced to seek out alternatives to state electricity, which could not provide more than a few hours of power per day.[28] According to Lebanese customs data, imports of solar panels went from 752 tons in 2020 to 12,958 tons in 2021, then spiked to 82,291 tons in 2022 (due to anticipated tariff adjustments), before returning to 29,023 tons in 2023, reflecting a return to the previous growth trend, as shown in Figure 1.[29]

16. PVKnowHow. 2025. "Lebanon Solar Panel Manufacturing | Market Insights Report." Available at: https://www.pvknowhow.com/solar-report/lebanon/

17. Worldometer. 2025. "Lebanon Population." Available at: https://www.worldometers.info/world-population/lebanon-population/

18. World Bank. 2025. "Lebanon – Land Area (sq. km)." Available at: https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=LB

19. World Bank. 2025. "Lebanon – GDP (current USD)." Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=LB

20. Rosen Solar Energy Co., Ltd. 2025. "Cyprus to Add 159 MW of New PV Capacity by 2024." Available at: https://www.rosenpv.com/news/cyprus-to-add-159-mw-of-new-pv-capacity-by-84709608.html

21. Worldometer. 2025. "Cyprus Population." Available at: https://www.worldometers.info/world-population/cyprus-population/

22. World Bank. 2025. "Cyprus – Country Profile." Available at: https://databank.worldbank.org/reports aspx?country=CYP&source=2

23. World Bank. 2025. "Jordan – GDP (current US$)." Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=JO

24. PVKnowHow. 2025. "Jordan Solar Tender Deadline Extended: 200 MW Project's Critical Update." Available at: https://www.pvknowhow.com/news/jordan-solar-tender-deadline-extended-200-mw-projects-critical-update/

25. Worldometer. 2025. "Jordan Population." Available at: https://www.worldometers.info/world-population/jordan-population/

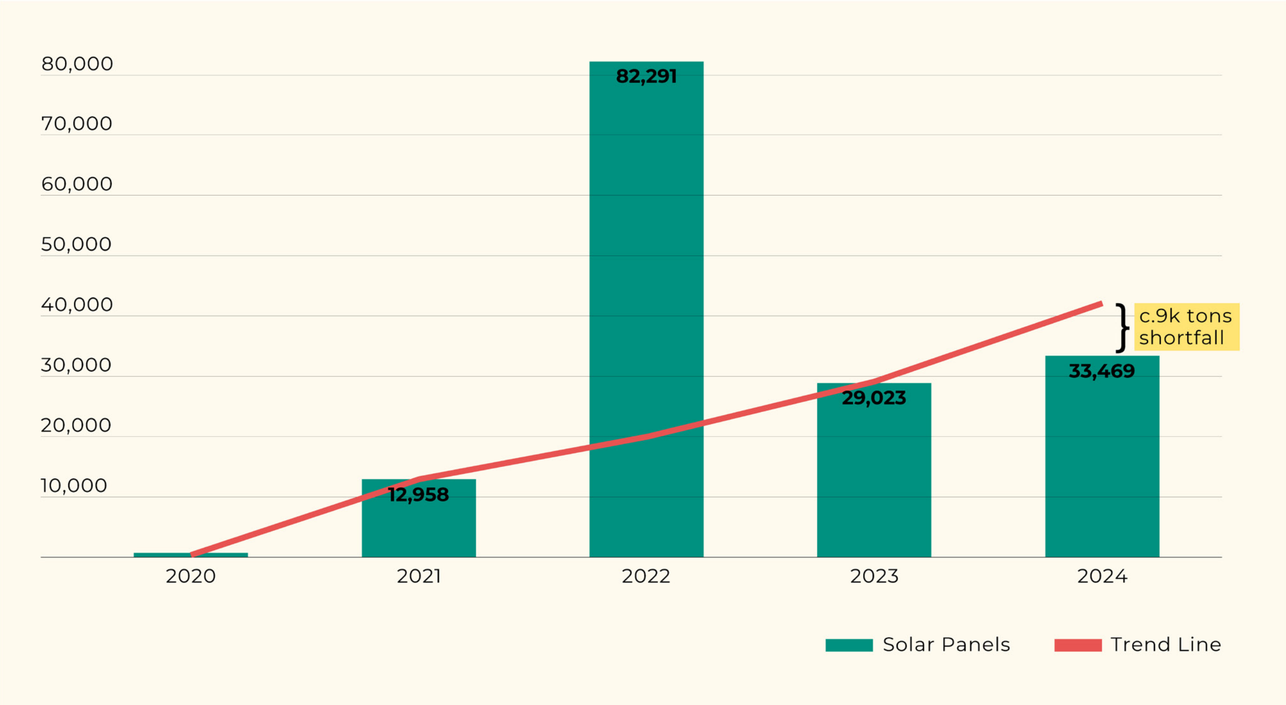
26. World Bank. 2025. "Jordan – Country Profile." Available at: https://databank.worldbank.org/reports.aspx?source=2&country=JOR

27. World Bank. 2025. "Cyprus – GDP (current US$)." Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CY

28. Taha, S. and Akel, J. 2024. In World Energy Council Report. Available at: https://www.worldenergy.org/experiences/lebanon-energy-transition

29. Lebanese Customs Administration (n.d.). Available at: http://www.customs.gov.lb/home.aspx]

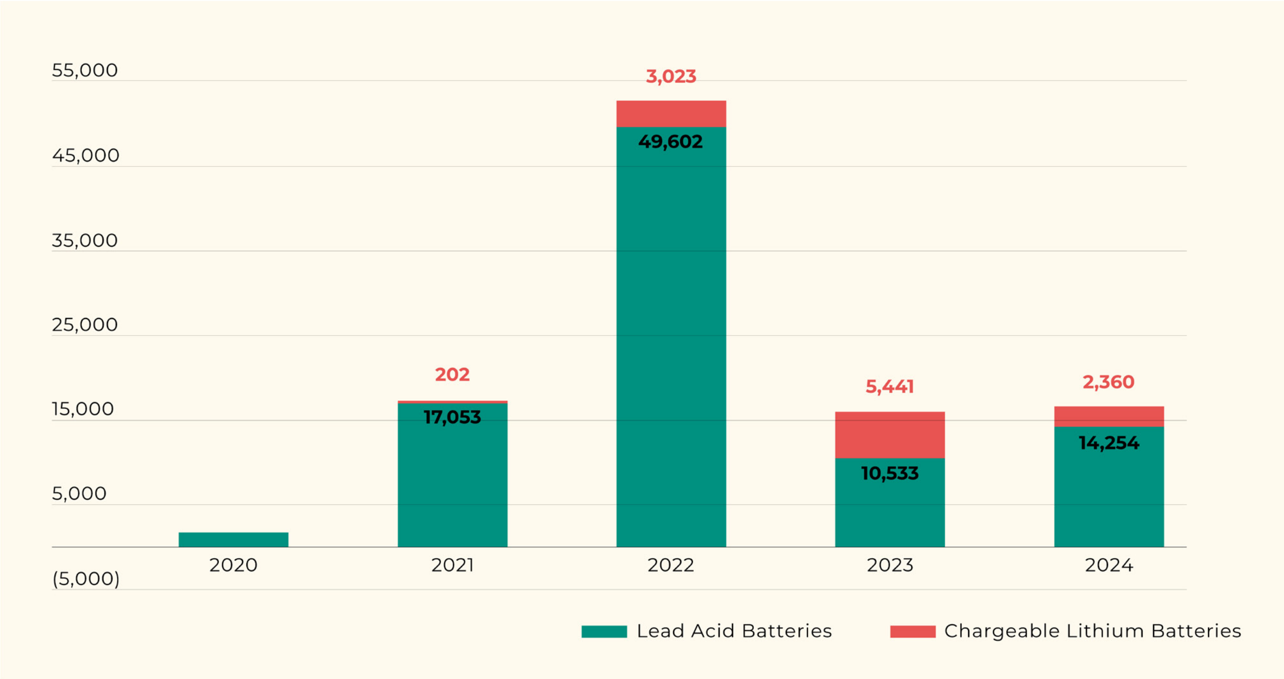
Figure 1: Solar panels imports to Lebanon (tons/year)[30]



Between 2020 and 2022, along with the rise of solar panels, there was a massive increase in lithium-ion batteries imported into the Lebanese market, as shown in Figure 2. This increase reflects Lebanon›s transition to renewable energy sources and its need for reliable energy storage to supplement the national grid. Lebanon also imported more than 49,000 tons of lead-acid batteries in 2022, as shown in Figure 2, with South Korea, Turkey, and China as major suppliers. However, it is important to recognize that not all of these imports are for household energy storage, as some are designated for vehicles.

30. Lebanese Customs Administration (n.d.). Available at: http://www.customs.gov.lb/home.aspx]

Figure 2: Lebanon net imports of chargeable batteries (tons/year)[31]



31. Lebanese Customs Administration (n.d.). Available at: http://www.customs.gov.lb/home.aspx]

Emissions Rebound: A Reversal of Progress

The war interrupted this autonomous transition to solar energy. The loss of solar capacity means that communities are returning to diesel generators, which emit around 900–1,000 gCO_2eq/kWh. This is over 20 times higher than solar's lifecycle emissions (~41 gCO_2/kWh for rooftop solar), and vastly more than solar's zero point-of-use emissions.[32]

Based on an estimated wartime destruction of 400,000–500,000 panels[33] equivalent to 150–200 MW of capacity, a rough estimate of additional CO_2 emissions can be calculated,[34] using a capacity factor of 19.8% (0.198), typical for Lebanese rooftop solar:[35]

For 150 MW ≈ 260,172 MWh/year.
For 200 MW ≈ 346,896 MWh/year.

To estimate the emissions impact, we apply a range of displacement factors based on real-world generation and emissions data for Lebanon.[36]

Recent reports show that Lebanon's public grid now supplies only a small fraction of national electricity demand, often just a few hours per day, with the vast majority covered by private diesel generators. According to estimates, diesel currently provides around 70–90% of actual electricity consumed while the grid contributes only 10–30%.[37,38] Using this mix rather than the "diesel-only" or "grid-only" cases implies that the true emissions impact lies between the two extremes we reported, for example around 276,917–300,384 tCO_2 per year for the counterfactual panels not installed in 2024, if we assume an 80/20 diesel-grid split.

However, as Figures 1 and 2 indicate, the loss of solar capacity is not limited to the PVs that were destroyed, but also to the PVs that were never imported, likely as a result of the uncertainty and losses incurred during the war. The steady trend observed since the crisis (the artificial spike in 2022 notwithstanding) shows a distinct drop in the imports of panels and batteries in 2024. When this shortfall is added to the calculations

32. Solar.com. 2025. "What is the Carbon Footprint of Solar Panels?" Available at: https://www.solar.com/learn/what-is-the-carbon-footprint-of-solar-panels/

33. El Amine, Y. 2025. Pathways for energy justice in Lebanon's post-war reconstruction. Arab Reform Initiative. Available at: https://www.arab-reform.net/publication/pathways-for-energy-justice-in-lebanons-post-war-reconstruction/

34. MoE/UNDP/GEF. 2024. Lebanon's National Greenhouse Gas Inventory Report. Beirut, Lebanon. Available at: https://unfccc.int/sites/default/files/resource/CC%20Greenhouse%20Gas%20NIR%20Report%20-%20Final.pdf

35. UNDP. 2017. "Lebanon: Derisking Renewable Energy Investment." Available at: https://www.undp.org/sites/g/files/zskgke326/files/2022-09/DREI%20Lebanon%20Full%20Report%20%28English%29%20%28Sep%202017%29%20%28FINAL%29.pdf

36. Heath, G., Macknick, J., & Newmark, R. 2012. Life cycle greenhouse gas emissions from solar photovoltaics. National Renewable Energy Laboratory (NREL). Available at: https://docs.nrel.gov/docs/fy13osti/56487.pdf

37. Human Rights Watch. 2023. "Cut Off From Life Itself: Lebanon's Failure on the Right to Electricity." Available at: https://www.hrw.org/report/2023/03/09/cut-life-itself/lebanons-failure-right-electricity

38. ESMAP/World Bank. 2020. Distributed Power Generation for Lebanon: Market Assessment and Policy Pathways. Available at: https://documents1.worldbank.org/curated/en/353531589865018948/pdf/Distributed-Power-Generation-for-Lebanon-Market-Assessment-and-Policy-Pathways.pdf

(row 2), the total excess emissions constitute an alarming reversal in a country already facing environmental strain.[39]

Table 2: Estimated solar panel losses, associated CO_2 emissions, and costs of excess emissions in Lebanon

	Panels Destroyed (000s	**Estimated Capacity Loss (MW)**	**Replacement Source**	**Additional CO_2 Emissions (tCO_2/year)**	**Lower bound estimated cost of added emissions (in millions of USD/year)**	**Upper bound estimated cost of added emissions (in millions of USD/year)**	**Notes/ Sources (see technical appendix for details)**
Lebanon actual destruction[40]	400-500	150-200	Diesel Generators	247,163 - 329,551	12.4 - 16.5	37.1 - 49.4	Emission factor ~0.95 tCO_2/MWh
			National Grid	184,722 - 246,296	9.2 - 12.3	27.7 - 36.9	Emission factor ~0.71 tCO_2/MWh
			Current mix	234,675 - 312,900	11.7 - 15.6	35.2 - 46.9	Generator-grid mix: 80-20
Lebanon counterfactual (panels not imported due to conflict, 2024)	480	177-192	Diesel Generators	291,653 - 316,369	14.6 - 15.8	43.7 - 47.5	Emission factor: 0.95 tCO_2/MWh
			National Grid	217,972 - 236,444	10.9 - 11.8	32.7 - 35.5	Emission factor: 0.71 tCO_2/MWh
			Current mix	276,917 - 300,384	13.8 - 15.0	41.5 - 45.1	Generator-grid mix: 80-20
Total	**880-980**	**327-392**	**Diesel Generators**	**538, 821 - 645,920**	**26.9 - 32.3**	**80.8 - 96.9**	
			National Grid	**402,694 - 482,740**	**20.1 - 24.1**	**60.4 - 72.4**	
			Current mix	**511,595 - 613,284**	**25.6 - 30.7**	**76.7 - 92.0**	

39. Author's calculation based on data from Low Carbon Power. 2023. Available at: https://lowcarbonpower.org/region/Lebanon

40. Tsagas, I. 2024. "Israeli strikes destroy 150–200 MW of solar in Lebanon." PV Magazine, December 16, 2024. Available at: https://www.pv-magazine.com/2024/12/16/israeli-strikes-destroy-150-200-mw-of-solar-in-lebanon/

Scaling the Findings: Lebanon's total solar capacity has increased from around 450 MW in 2022 to more than 1,000 MW by mid-2023. Losing 150-200 MW thus corresponds to a 15-20% reduction in the national solar output. With Lebanon's electricity sector emitting approximately 5 million tCO_2/year, this loss represents an additional 5.0-6.6% of sectoral emissions if replaced by diesel or 4.7-6.2% if replaced by the grid average.[41]

Monetizing Added Emissions: Carbon costs can vary widely depending on the valuation approach. If we use a conservative benchmark of $50 per ton of CO_2,[42] then the added emissions, using an 80/20 diesel-grid split, equate to:

◊ 150 MW (low estimate) = 234,675 tCO2/year = $11,733,940/year
◊ 200 MW (high estimate) = 312,900 tCO2/year = $15,645,000/year

And for the "counterfactual" panels that were never imported:
◊ 177 MW (low estimate) = 276,917 tCO2/year = $13,845833/year
◊ 192 MW (high estimate) = 300,384 tCO2/year = $15,019209/year

This amounts to a total cost of at least $25 to 30 million per year.

However, more comprehensive costing approaches, which include non-market damages and climate tipping points, hint at much higher values, potentially $150 per ton or more.[43] This would imply that the true monetized cost of Lebanon's destroyed solar infrastructure could be several orders of magnitude higher than the conservative figures reported here.

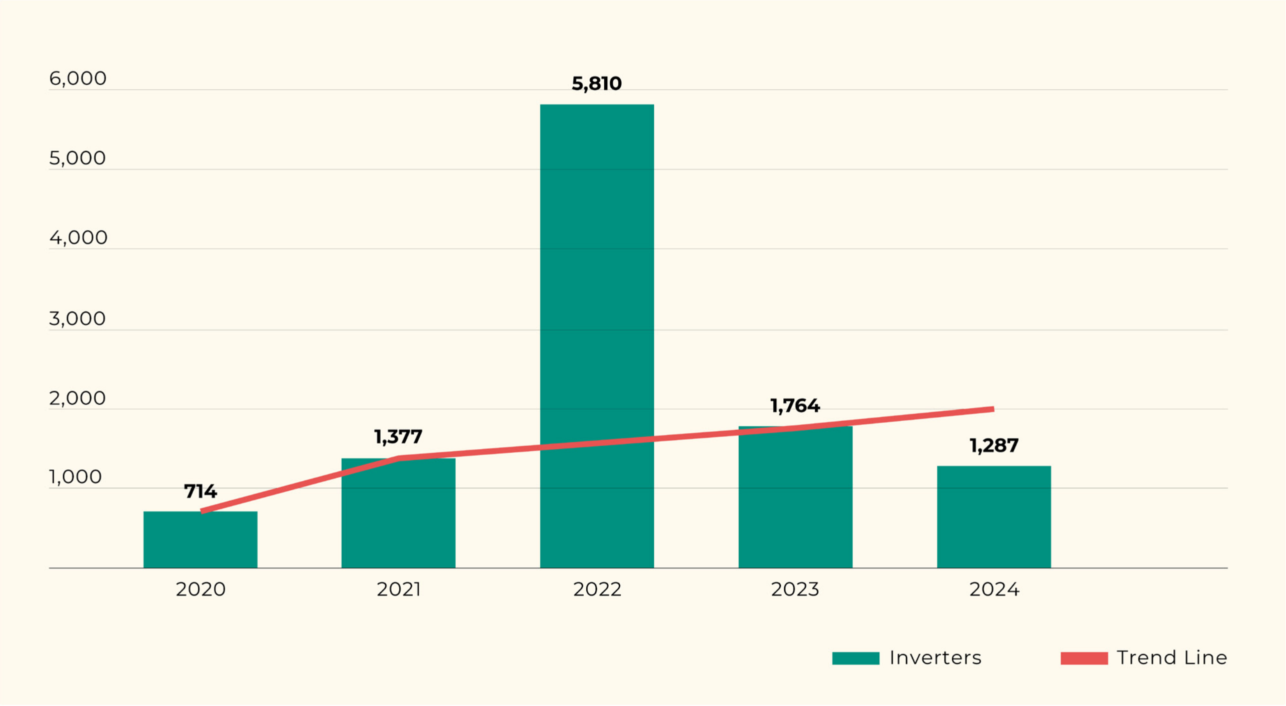
Checking Robustness: Our estimates are based on the trends observed in solar panel imports. To further confirm those results, we examined the annual series of imports of inverters (Figure 3). Lebanon imported $24.8 million inverters in 2021, $143.4 million in 2022, and $50.2 million in 2023 (showing a similar spike during the 2022 adoption of the new exchange rate for the calculation of tariffs). As is the case with solar panel imports, the pre-2022 growth trend recovered in 2023 but was disrupted in 2024. The same pattern of a shortfall in imports in 2024, seen in Figures 1 and 2, is also evident in Figure 3.

41. Dagher, L., Diab, S., & Zwein, R. 2025. "From Crisis to Opportunity: Advancing Solar Energy in Lebanon Through Effective Policymaking." Arab Reform Initiative. Available at: https://www.arab-reform.net/publication/from-crisis-to-opportunity-advancing-solar-energy-in-lebanon-through-effective-policymaking/

42. U.S. Environmental Protection Agency (EPA). 2023. Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances. Available at: https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf

43. Soergel, B., Kriegler, E., Weindl, I., Rauner, S., Dirnaichner, A., Ruhe, C., Hofmann, M., Bauer, N., Bertram, C., Bodirsky, B. L., Leimbach, M., Leininger, J., Levesque, A., Luderer, G., Pehl, M., Wingens, C., Baumstark, L., Beier, F., Dietrich, J. P., Humpenöder, F., von Jeetze, P., Klein, D., Koch, J., Pietzcker, R., Strefler, J. & Lotze-Campen, H. 2021. A sustainable development pathway for climate action within the UN 2030 Agenda. Nature Climate Change, 11, pp. 656–664. Available at: https://www.nature.com/articles/s41558-021-01098-3

Figure 3: Lebanon inverters net imports (tons)



Agricultural Setbacks and Long-Term Risks

In rural areas, especially along the southern border, solar panels had been used to operate irrigation systems. These were typically low-cost, daylight-only solutions without battery storage. Not only did the destruction of these systems cut access to water, but it also threatened food security and forced a return to diesel water pumps, further compounding emissions.[44] The war also led to the destruction of more than 47,000 olive trees, major damage to greenhouses, and soil pollution from phosphorus and heavy metals, pointing to a wider ecological collapse.[45] In fact, the loss of these agricultural solar systems accounted for approximately 10-15% of Lebanon›s solar generation capacity, along with financial losses of $150-300 million.

The imports of lithium-ion batteries have also brought increased battery waste, which estimates indicate could rise from 33,444 tons in 2022 to 145,814 tons by 2040, primarily due to higher usage of solar system batteries. The destruction of infrastructure and disruptions caused by the Israel conflict further accelerate the turnover of these batteries as damaged or abandoned solar systems contribute heavily to rising e-waste.[46]

44. Tahrir Institute for Middle East Policy. 2023. "Israel's Environmental and Economic Warfare on Lebanon." Available at: https://timep.org/2023/11/28/israels-environmental-and-economic-warfare-on-lebanon/ [UNDP (2023)

45. Low Carbon Power. 2023. "Lebanon." Available at: https://lowcarbonpower.org/region/Lebanon

46. UNDP. 2024. "Assessment of E-Waste and Batteries in Lebanon." Available at: https://www.undp.org/sites/g/files/zskgke326/files/2024-07/tadwir_e-waste_report_10.07.2024_1.pdf

Where Do We Go from Here?

Despite the destruction, Lebanon still has vast unexploited solar potential. A 2021 study estimated that rooftop solar alone could produce over 28.1 TWh/year, which is more than twice the country's total energy consumption in 2019.[47] But this opportunity can only be seized with targeted recovery efforts. Damage assessments by groups such as the National Council for Scientific Research (CNRS), the Beirut Urban Lab, and the Environment and Sustainable Development Unit at the American University of Beirut (AUB) will be essential to identify which types of solar infrastructure were most affected and where rebuilding should begin.

Meanwhile, a new energy strategy must distinguish between residential, commercial, and agricultural solar needs. Rebuilding efforts should focus on off-grid solar for farms and critical services, support storage solutions for homes, and create incentives for commercial resilience. If not, the country risks deepening its reliance on polluting fuels just after it was beginning to move beyond them.[48] These emissions not only represent a heavy burden locally but, more importantly, put forward a global cost. Diesel generators and conventional grids produce highly toxic pollutants (CO2, SO2, Pb, and particulate matter at various sizes), which inevitably lead to detrimental effects on public health and rising temperatures worldwide. Lebanon's energy choices are not isolated as they are very much endured beyond its borders, undermining climate goals and contributing to the shared burden of global warming. Ultimately, what happens in Lebanon not only affects the people in its region but also contributes to a global problem.

This piece is cross-posted on the Critical Ecologies Lab in the Mediterranean East (CELME) website at the American University of Beirut.

47. Nasr, J. et al. 2021. "Lebanon Solar Rooftop Potential Assessment using Buildings Segmentation from Aerial Images." arXiv. Available at: https://arxiv.org/abs/2111.11397

48. Arab Reform Initiative. 2025. "Rebuilding Lebanon: Clean Energy Access and Challenges." Available at: https://www.arab-reform.net/publication/rebuilding-lebanon-clean-energy-access-and-challenges/

Technical appendix

- MW per capita: Installed capacity ÷ population (per million people)
  - Lebanon: 1005 / 5.77 ≈ 174
  - Cyprus: 797 / 1.37 ≈ 582
  - Jordan: 1800 / 11.5 ≈ 156

- MW per area: Installed capacity ÷ area (per 1,000 km^2)
  - Lebanon: 1005 / 10.2 ≈ 98.2
  - Cyprus: 797 / 9.25 ≈ 86.2
  - Jordan: 1800 / 88.8 ≈ 20.3

- MW per GDP: Installed capacity ÷ GDP (per $1billion)
  - Lebanon: 1005 / 20.08 ≈ 50.05
  - Cyprus: 797 / 36.6 ≈ 21.8
  - Jordan: 1800 / 53.4 ≈ 33.7

- Annual energy generation from lost solar capacity:[49]

  Annual MWh = Capacity (MW) × 8760 hours/year × Capacity Factor

  Using a capacity factor of 19.8% (0.198), typical for Lebanese rooftop solar:[50]
  - 150 MW × 8760 × 0.198 ≈ 260,172 MWh/year.
  - 200 MW × 8760 × 0.198 ≈ 346,896 MWh/year.

- If lost generation is replaced by diesel generators emitting ~0.95 tCO_2/MWh:
  - 150 MW diesel: 260,172 × 0.95 ≈ 247,163 tCO_2/year
  - 200 MW diesel: 346,896 × 0.95 ≈ 329,551 tCO_2/year

- If replaced by the Lebanese grid average (~0.71 tCO_2/MWh):
  - 150 MW grid: 260,172 × 0.71 ≈ 184,722 tCO_2/year
  - 200 MW grid: 346,896 × 0.71 ≈ 246,296 tCO_2/year

- Annual energy generation from "missing" solar capacity:
  Annual MWh = Capacity (MW) × 8760 hours/year × Capacity Factor (19.8%)
  Shortfall (tons) = 42,116 – 33,469 = 8,648
  Shortfall (panels) = 8,648,000 Kg / 18 Kg per panel[51] = 480,444
  Shortfall (MW)low = 480,444 panels / 2,700 panels[52] per MW = 177
  Shortfall (MW)high = 480,444 panels / 2,500 panels per MW = 192

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$177 \text{ MW} \times 8{,}760 \times 0.198 \approx 307{,}002 \text{ MWh/year}$
$192 \text{ MW} \times 8{,}760 \times 0.198 \approx 333{,}020 \text{ MWh/year}$

◊ If generation replaced by diesel (~0.95 tCO_2/MWh):
$307{,}002 \times 0.95 \approx 291{,}652 \text{ } tCO_2\text{/year}$
$333{,}020 \times 0.95 \approx 316{,}369 \text{ } tCO_2\text{/year}$

◊ If generation replaced by grid (~0.71 tCO_2/MWh):
$307{,}002 \times 0.71 \approx 217{,}971 \text{ } tCO_2\text{/year}$
$333{,}020 \times 0.71 \approx 236{,}444 \text{ } tCO_2\text{/year}$

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