

## **Stand out of our Light: Loss of Photo Voltaic Infrastructure from Israel's War on Lebanon 2023**

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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 5000.<sup>1,2,3</sup> Armed aggression did not end with the ceasefire, and continues until the time of writing. The resulting human and material costs are immense. A first assessment of the damage was summarized in a report by the National Council for Scientific Research.<sup>4</sup> The focus of this paper is on a narrower but important facet of the war's toll that is often overlooked: the increase in greenhouse gas (GHG) emissions as a result of the destruction of Photo Voltaic (PV) panels. Some of this damage is severe in ways that are often missed, such as the loss of the rapidly growing solar energy infrastructure in the country. As Lebanon's public electricity system continued to collapse in recent years, solar power had emerged as one of the most viable (and in many cases the only) alternative source of energy for households, businesses, and farms.<sup>5</sup> The conflict did not just destroy this infrastructure; it abruptly reversed years of organic transition toward clean energy, leaving thousands more reliant again on diesel generators and fossil fuels and directly increasing carbon emissions and environmental degradation.<sup>6</sup> 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, with the inevitable 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 energy trajectory of pre-conflict energy has not only been interrupted, but it has actively been reversed and investment in solar energy to replace the destroyed infrastructure will likely remain shy as long as the risk of aggression continues.<sup>7</sup> Our paper is focused on the conflict's negative impact on solar

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<sup>1</sup> [Human Rights Watch (2025). *World Report 2025: Lebanon*. Human Rights Watch. Available at: <https://www.hrw.org/world-report/2025/country-chapters/lebanon>]

<sup>2</sup> [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>]

<sup>3</sup> [Reuters (2025). 'Can Lebanon disarm Hezbollah?'. Available at: <https://www.reuters.com/world/middle-east/can-lebanon-disarm-hezbollah-2025-08-06/>]

<sup>4</sup> [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: [chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cnrs.edu.lb/Library/Files/Uploaded/Files/CNRS-L\\_report\\_on\\_Israeli\\_Offensive\\_against\\_Lebanon\\_2023-2024\\_English.pdf](chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cnrs.edu.lb/Library/Files/Uploaded/Files/CNRS-L_report_on_Israeli_Offensive_against_Lebanon_2023-2024_English.pdf)]

<sup>5</sup> [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/>]

<sup>6</sup> [Low Carbon Power (2023). 'Lebanon'. Available at: <https://lowcarbonpower.org/region/Lebanon>]

<sup>7</sup> [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](https://www.undp.org/sites/g/files/zskgke326/files/2025-07/report_socioeconomic-impacts-lebanon-2024-war-english.pdf)]

electricity generation and the ensuing emissions. It goes without saying that the conflict had much broader environmental repercussions including, but not limited to, the emissions caused by the fighter jets, the debris caused by the destruction of infrastructure, and the pollution from the Israeli forces' use of white phosphorus. Recovery and rehabilitation is itself likely to be carbon heavy also, as clearing rubble and rebuilding are both energy intensive activities.

### **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:<sup>8</sup>

- Residential systems, often 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 diesel generators and cutting emissions at the neighbourhood level.<sup>9</sup> The economic collapse which started in late 2019, and the ensuing fuel crisis in 2020 heralded a period of rapid uptake of rooftop and distributed solar systems. By the end of 2022, Lebanon had installed approximately 690 MW of cumulative solar PV capacity, up from 90 MW in 2020, which constitutes a whopping 667% increase in just 2 years.<sup>10</sup> In 2023, this rapid growth continued as the share of small-scale residential PV's in newly installed capacity surged from 8.56% in 2022 to 18.15%.<sup>11</sup>
- 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, have likely stopped operations, and caused a fallback to less environmentally friendly backup power.
- Agricultural solar systems are typically small, and they consist of off-grid panels that power irrigation pumps. These systems include 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.<sup>12</sup>

### **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 exceeded

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<sup>8</sup> [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/>]

<sup>9</sup> [Low Carbon Power (2023). 'Lebanon'. Available at: <https://lowcarbonpower.org/region/Lebanon>]

<sup>10</sup> [PVknowhow.com (2025). Available at: <https://www.pvknowhow.com/news/lebanon-solar-investment-panel-imports-500-million/>]

<sup>11</sup> [Climatescope (2024). 'Lebanon Market Profile'. Available at: <https://www.global-climatescope.org/markets/lebanon>]

<sup>12</sup> [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>]

\$500 million, which amounts to close to 2.5% of GDP.<sup>13</sup> By mid-2023, Lebanon managed to achieve a total of 1,005 MW of installed capacity with the vast majority being residential and unregulated.<sup>14</sup> This is equivalent to around 30% of the country's total installed electricity production of close to 3,500 MW.<sup>15</sup>

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 comparator countries 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 higher density of solar panels and more solar capacity per dollar of GDP than either Jordan or Cyprus.

**Table 1: Lebanon Solar Capacity Compared to Neighbouring Countries**

Country	Installed solar capacity (MW)	Solar capacity per capita (MW/million people)	Solar capacity per area basis (MW/1000km <sup>2</sup> )	Solar capacity relative to GDP (MW/billion USD)
Lebanon	1005 <sup>16</sup>	174 <sup>17</sup>	98.2 <sup>18</sup>	50.05 <sup>19</sup>
Cyprus	797 <sup>20</sup>	582 <sup>21</sup>	86.2 <sup>22</sup>	33.7 <sup>23</sup>
Jordan	1,800 <sup>24</sup>	156 <sup>25</sup>	20.3 <sup>26</sup>	21.8 <sup>27</sup>

<sup>13</sup> [PVknowhow.com (2025). Available at: <https://www.pvknowhow.com/news/lebanon-solar-investment-panel-imports-500-million/>]

<sup>14</sup> [PVknowhow (2025). 'Lebanon Solar Panel Manufacturing | Market Insights Report'. Available at: <https://www.pvknowhow.com/solar-report/lebanon/>]

<sup>15</sup> [IEA (2025). 'Lebanon - Electricity'. International Energy Agency. Available at: <https://www.iea.org/countries/lebanon/electricity>]

<sup>16</sup> [PVKnowHow (2025). 'Lebanon Solar Panel Manufacturing | Market Insights Report'. Available at: <https://www.pvknowhow.com/solar-report/lebanon/>]

<sup>17</sup> [Worldometer (2025). 'Lebanon Population'. Available at: <https://www.worldometers.info/world-population/lebanon-population/>]

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

<sup>19</sup> [World Bank (2025). 'Lebanon – GDP (current US\$)'. Available at: <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=LB>]

<sup>20</sup> [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>]

<sup>21</sup> [Worldometer (2025). 'Cyprus Population'. Available at: <https://www.worldometers.info/world-population/cyprus-population/>]

<sup>22</sup> [World Bank (2025). 'Cyprus – Country Profile'. Available at: <https://databank.worldbank.org/reports.aspx?country=CYP&source=2>]

<sup>23</sup> [World Bank (2025). 'Jordan – GDP (current US\$)'. Available at: <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=JO>]

<sup>24</sup> [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/>]

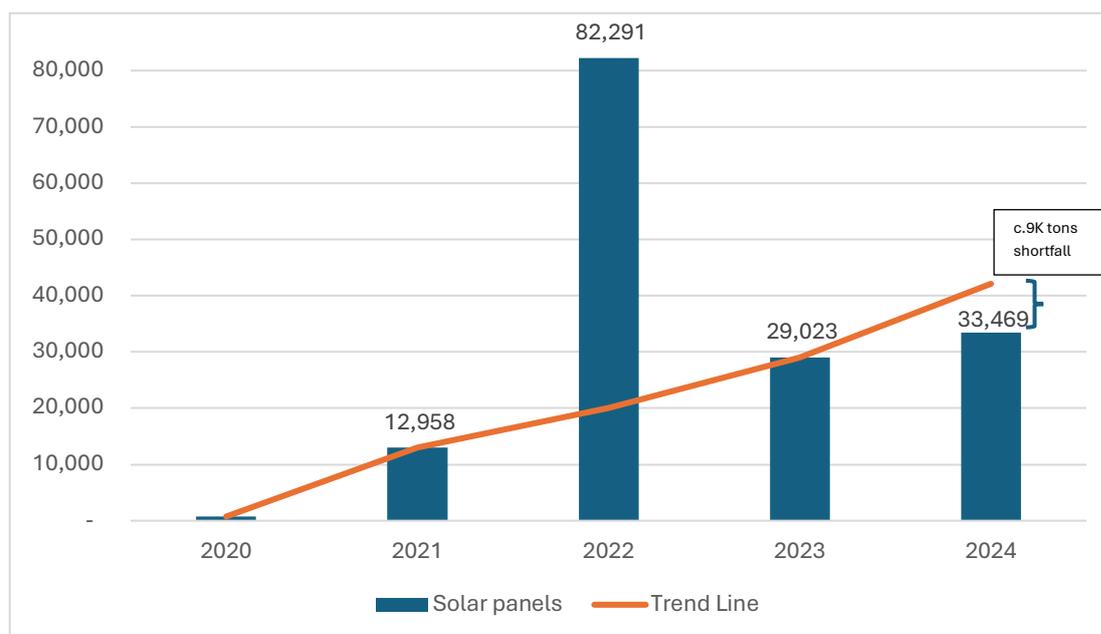
<sup>25</sup> [Worldometer (2025). 'Jordan Population'. Available at: <https://www.worldometers.info/world-population/jordan-population/>]

<sup>26</sup> [World Bank (2025). 'Jordan – Country Profile'. Available at: <https://databank.worldbank.org/reports.aspx?source=2&country=JOR>]

<sup>27</sup> [World Bank (2025). 'Cyprus – GDP (current US\$)'. Available at: <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CY>]

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.<sup>28</sup> Furthermore, according to Lebanese Customs data (Lebanese Customs, 2024), imports of solar panels went from 784 tons in 2020, to 12,983 tons in 2021, then spiked to 82,743 tons in 2022 (due to anticipated tariff adjustments), before returning to 29,768 tons in 2023, reflecting a return to the previous growth trend, as shown on Chart 1.<sup>29</sup>

**Chart 1: Solar Panels Imports to Lebanon (tons/year)<sup>30</sup>**



Between 2020 and 2022, along with the rise of solar panels, there has been a massive increase in lithium-ion batteries imported into the Lebanese market, as shown on Chart 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 over 49 thousand tons of lead-acid batteries in 2022, as also shown on Chart 2, with major suppliers including South Korea, Turkey, and China. However, it is important to recognise that not all of these imports are used for household energy storage, as some are designated for vehicles.

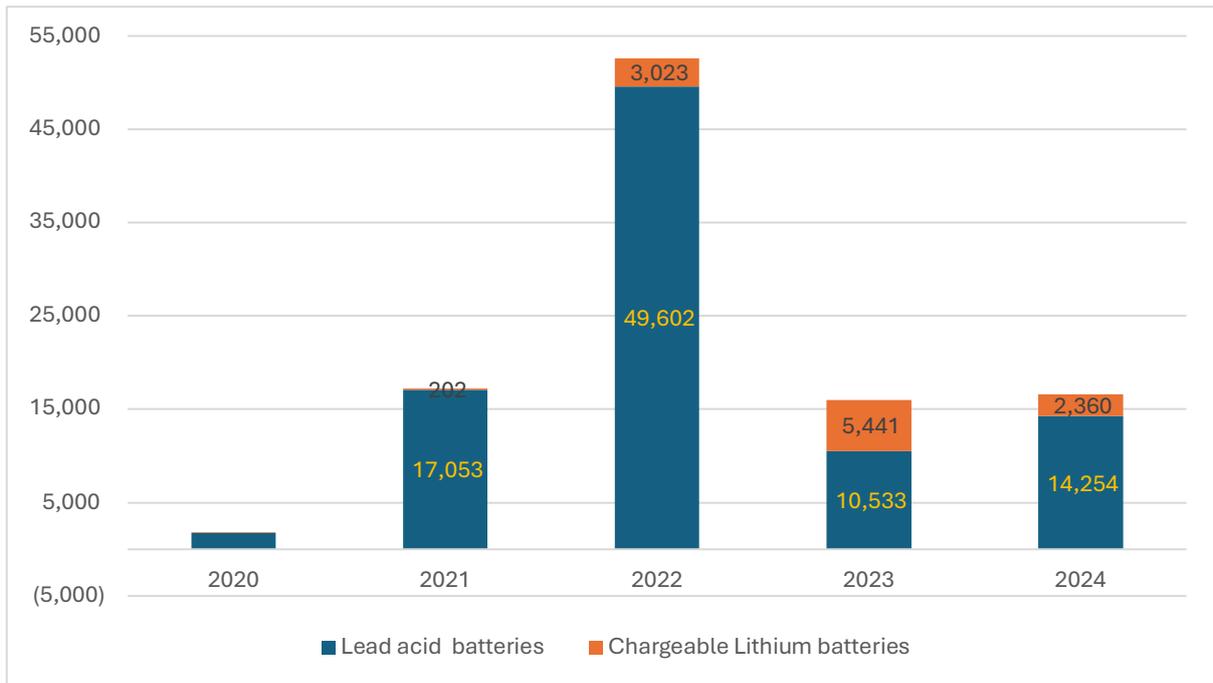
**Chart 2: Lebanon Net Imports of Chargeable Batteries (tons/year)<sup>31</sup>**

<sup>28</sup> [Taha, S. and Akel, J. (2024). In World Energy Council Report. Available at: <https://www.worldenergy.org/experiences/lebanon-energy-transition>]

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

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

<sup>31</sup> [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. The loss of solar capacity means that communities are going back to diesel generators, which emit around 900–1,000 gCO<sub>2</sub>eq/kWh. This is over twenty times higher than solar’s lifecycle emissions (~41 gCO<sub>2</sub>/kWh for rooftop solar), and vastly more than solar’s zero point-of-use emissions.<sup>32</sup>

Based on an estimated destruction of 400,000–500,000 panels (Arab Reform Initiative, 2025; PV Magazine, 2024), equivalent to 150–200 MW of capacity, a rough estimate of additional emissions can be calculated,<sup>33</sup> using a capacity factor of 19.8% (0.198), typical for Lebanese rooftop solar:<sup>34</sup>

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.<sup>35</sup>

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

<sup>32</sup> [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/>]

<sup>33</sup> [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>]

<sup>34</sup> [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>]

<sup>35</sup> [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>]

diesel generators. According to estimates, diesel currently provides around 70–90% of actual electricity consumed while the grid contributes only 10–30%.<sup>36,37</sup> 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<sub>2</sub> per year for the counterfactual panels not installed in 2024, if we assume an 80/20 diesel-grid split.

However, as Charts 1 and 2 of capital imports for solar installations indicate, the loss of solar capacity is not limited to the PVs destroyed, but also to the PVs 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 (row 2), the total excess emissions shows an alarming reversal in a country already facing environmental strain.<sup>38</sup>

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<sup>36</sup> [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>]

<sup>37</sup> [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>]

<sup>38</sup> [Author's calculation based on data from Low Carbon Power (2023). Available at: <https://lowcarbonpower.org/region/Lebanon>]

**Table 2: Estimated Solar Panel Losses, Associated CO<sub>2</sub> Emissions, and Costs of Excess Emissions in Lebanon**

	<b>Panels Destroyed (000s)</b>	<b>Estimated Capacity Loss (MW)</b>	<b>Replacement Source</b>	<b>Additional CO<sub>2</sub> Emissions (tCO<sub>2</sub>/year)</b>	<b>Lower bound estimate of cost of added emissions (in millions of USD/year)</b>	<b>Upper bound estimate of cost of added emissions (in millions of USD/year)</b>	<b>Notes / Sources (see technical appendix for details)</b>
Lebanon actual destruction <sup>39</sup>	400-500	150-200	Diesel Generators	247,163 - 329,551	12.4 - 16.5	37.1 - 49.4	Emission factor ~0.95 tCO <sub>2</sub> /MWh
			National Grid	184,722 - 246,296	9.2 - 12.3	27.7 - 36.9	Emission factor ~0.71 tCO <sub>2</sub> /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 <sub>2</sub> /MWh
			National Grid	217,972 - 236,444	10.9 - 11.8	32.7 - 35.5	Emission factor: 0.71 tCO <sub>2</sub> /MWh
			Current mix	276,917 - 300,384	13.8 - 15.0	41.5 - 45.1	Generator-grid mix: 80-20
<b>Total</b>	<b>880-980</b>	<b>327-392</b>	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	

<sup>39</sup> [Tsagas, I. (2024). 'Israeli strikes destroy 150–200 MW of solar in Lebanon'. pv magazine, 16 December. 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 over 1,000 MW by mid-2023. Losing 150-200 MW thus corresponds to a 15-20% reduction in national solar output. With Lebanon’s electricity sector emitting approximately 5 million tCO<sub>2</sub>/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**.<sup>40</sup>

**Monetizing Added Emissions:** Carbon costs can vary widely depending on the valuation approach. If we use a conservative benchmark of US\$50 per ton of CO<sub>2</sub> (World Bank; U.S. EPA), then the added emissions, using an 80/20 diesel-grid split, equate to:

- 150 MW (low estimate) = 234,675 tCO<sub>2</sub>/year = US\$11,733,940/year
- 200 MW (high estimate) = 312,900 tCO<sub>2</sub>/year = US\$15,645,000/year

And for the “counterfactual” panels that were never imported:

- 177 MW (low estimate) = 276,917 tCO<sub>2</sub>/year = US\$13,845,833/year
- 192 MW (high estimate) = 300,384 tCO<sub>2</sub>/year = US\$15,019,209/year

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

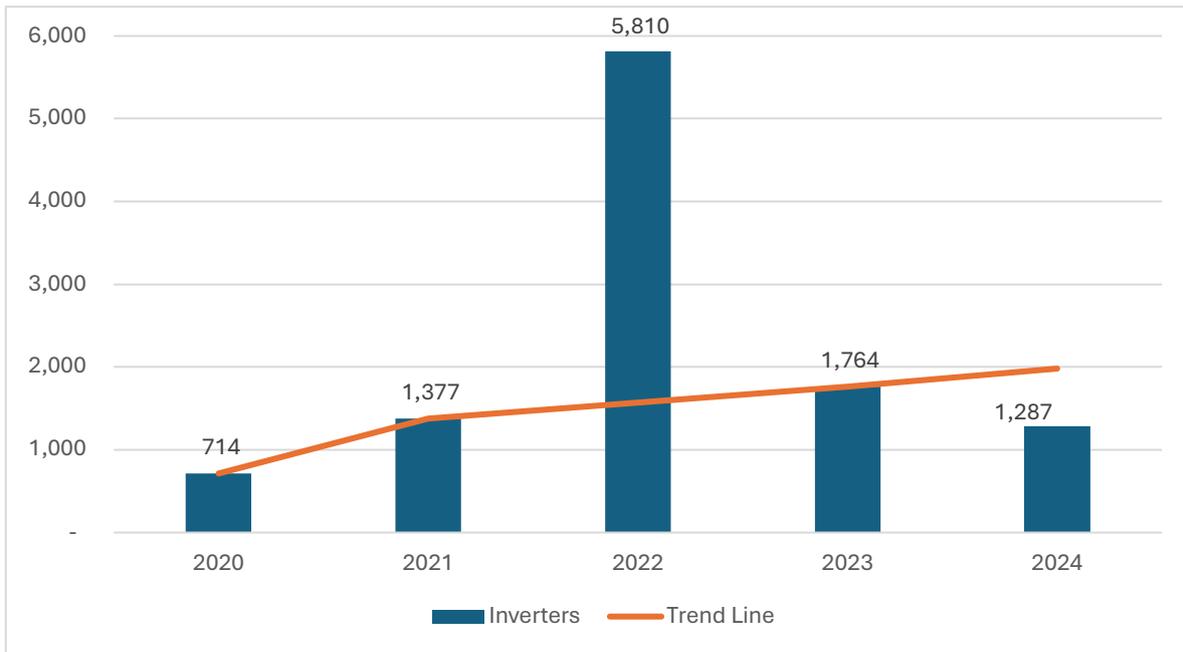
However, using more comprehensive costing approaches, which include non-market damages and climate tipping points, hint towards much higher values, potentially more than US\$150 per ton or more (Stern Review; Nature Climate Change, 2022). This would imply that the true monetized cost of Lebanon’s destroyed solar infrastructure could in fact be several orders of magnitude higher than the conservative figures reported here.

**Checking robustness:** since our estimates are based on the trends observed in solar panel imports, to further confirm our results, we look at the annual series of imports of inverters (Chart 3). Lebanon imported \$24.8M inverters in 2021, \$143.4M in 2022, and \$50.2M 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 is recovered in 2023, *but disrupted in 2024*. The same pattern of a shortfall in imports in 2024 seen in Charts 1 and 2 is also detected in Chart 3.

### **Chart 3: Lebanon Inverters Net Imports (tons)**

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<sup>40</sup> [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/>]



### 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.<sup>41</sup> The war also led to the destruction of over 47,000 olive trees, major damage to greenhouses, and the pollution of soil with white phosphorus and heavy metals, pointing to a wider ecological collapse.<sup>42</sup> 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 resulted in an increase in battery waste, which estimates indicate could increase from 33,444 tons in 2022, to 145,814 tons by 2040, primarily because of the increase in the use 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.**<sup>43</sup>

### Where do we go from here?

Despite the destruction, Lebanon still has vast unexploited solar potential. A 2021 study “Lebanon Solar Rooftop Potential Assessment using Buildings Segmentation from Aerial

<sup>41</sup> [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).

<sup>42</sup> [Low Carbon Power (2023). 'Lebanon'. Available at: <https://lowcarbonpower.org/region/Lebanon/>]

<sup>43</sup> [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](https://www.undp.org/sites/g/files/zskgke326/files/2024-07/tadwir_e-waste_report_10.07.2024_1.pdf)]

Images” 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.<sup>44</sup>

But this opportunity can only be seized with targeted recovery efforts. Damage assessments by groups like CNRS, the Beirut Urban Lab, and the Environment and Sustainable Development Unit at AUB will be essential for identifying which types of solar infrastructure were most affected and where rebuilding should start and accordingly, 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 when it was beginning to move beyond them.<sup>45</sup> 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 (CO, SO<sub>2</sub>, Pb and particulate matter at various sizes), which inevitably leads to detrimental effects on public health and rising temperatures worldwide. Thus, 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 does not only affect the people in its region but contributes to a problem felt by the world.

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

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<sup>44</sup> [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>]

<sup>45</sup> [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)

$$\text{Lebanon: } 1005 \div 5.77 \approx 174$$

$$\text{Cyprus: } 797 \div 1.37 \approx 582$$

$$\text{Jordan: } 1800 \div 11.5 \approx 156$$

- MW per area: Installed capacity ÷ area (per 1,000 km<sup>2</sup>)

$$\text{Lebanon: } 1005 \div 10.2 \approx 98.2$$

$$\text{Cyprus: } 797 \div 9.25 \approx 86.2$$

$$\text{Jordan: } 1800 \div 88.8 \approx 20.3$$

- MW per GDP: Installed capacity ÷ GDP (per billion USD)

$$\text{Lebanon: } 1005 \div 20.08 \approx 50.05$$

$$\text{Cyprus: } 797 \div 36.6 \approx 21.8$$

$$\text{Jordan: } 1800 \div 53.4 \approx 33.7$$

- Annual energy generation from lost solar capacity:<sup>46</sup>

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

Using a capacity factor of 19.8% (0.198), typical for Lebanese rooftop solar:<sup>47</sup>

$$150 \text{ MW} \times 8760 \times 0.198 \approx 260,172 \text{ MWh/year.}$$

$$200 \text{ MW} \times 8760 \times 0.198 \approx 346,896 \text{ MWh/year.}$$

- If lost generation is replaced by **diesel generators emitting ~0.95 tCO<sub>2</sub>/MWh** :

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<sup>46</sup>[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>]

<sup>47</sup> [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>]

150 MW diesel:  $260,172 \times 0.95 \approx 247,163$  tCO<sub>2</sub>/year

200 MW diesel:  $346,896 \times 0.95 \approx 329,551$  tCO<sub>2</sub>/year

- If replaced by the **Lebanese grid average** (~0.71 tCO<sub>2</sub>/MWh) :

150 MW grid:  $260,172 \times 0.71 \approx 184,722$  tCO<sub>2</sub>/year

200 MW grid:  $346,896 \times 0.71 \approx 246,296$  tCO<sub>2</sub>/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<sup>48</sup> = 480,444

Shortfall (MW)<sub>low</sub> = 480,444 panels ÷ 2,700 panels<sup>49</sup> per MW = 177

Shortfall (MW)<sub>high</sub> = 480,444 panels ÷ 2,500 panels per MW = 192

177 MW × 8,760 × 0.198 ≈ 307,002 MWh/year

192 MW × 8,760 × 0.198 ≈ 333,020 MWh/year

- If generation replaced by diesel (~0.95 tCO<sub>2</sub>/MWh):

$307,002 \times 0.95 \approx 291,652$  tCO<sub>2</sub>/year

$333,020 \times 0.95 \approx 316,369$  tCO<sub>2</sub>/year

- If generation replaced by grid (~0.71 tCO<sub>2</sub>/MWh):

$307,002 \times 0.71 \approx 217,971$  tCO<sub>2</sub>/year

$333,020 \times 0.71 \approx 236,444$  tCO<sub>2</sub>/year

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<sup>48</sup> [The Eco Experts (2025). 'How much do solar panels weigh?'. Available at: <https://www.theecoexperts.co.uk/solar-panels/weight/>]

<sup>49</sup> [EE Renewables (2025). 'How Many Solar Panels Needed to Generate 1 Megawatt?'. Available at: <https://www.eerenewables.co.uk/solar-guides/how-many-solar-panels-needed-to-generate-1-megawatt/>]

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