OPERATIONALISING THE NEXUS IN THE WATER SECTOR:

SOLARIZATION CASE STUDY

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EXECUTIVE SUMMARY

Lebanon's water sector is under acute stress. Years of economic collapse, chronic electricity shortages, conflict, and climate pressures have made reliable water access increasingly fragile. Public Water Establishments depend heavily on costly diesel generators to power pumping stations, draining budgets, disrupting services, and undermining public trust. In this context, solarization of water infrastructure has emerged as a practical, scalable solution capable of simultaneously delivering humanitarian, development, and peace outcomes, demonstrating the Humanitarian–Development–Peace (HDP) Nexus in action.

This paper examines the solarization of two water pumping stations in South Lebanon – Qaaqayet el-Snoubar and Insariyeh–Adloun – funded by AECID and implemented by Action Against Hunger. The case studies draw on technical and financial analysis, community-level feedback, and interviews with the South Lebanon Water Establishment (SLWE), municipalities, and humanitarian partners.

Together, these findings show tangible benefits in humanitarian, development and peace-building terms. Solarization dramatically reduces energy costs (by 60–80%), improves reliability of water supply, reduces environmental impact and strengthens institutional resilience, particularly during crisis periods. Increased water availability provided life-saving continuity to thousands of households, financial savings exceeding USD 115,000 annually allowed the local water establishment and municipalities to channel resources toward repairs, network upgrades, and other development priorities. Communities reported an 80% reduction in complaints, improved hygiene, and reduced household spending on trucked water. Stakeholders unanimously highlighted benefits extending well beyond technical performance, including enhanced trust in municipalities, and stronger acceptance of renewable energy at the community level.

The paper proposes four criteria for designing Nexus-aligned interventions, each grounded in an international benchmark, with practical applications both in solarization projects and in interventions more broadly:

1) Long-term impact (at least two years);
2) Integration of humanitarian, development and peace objectives;
3) Conflict-sensitive and resilience-oriented design;
4) Community engagement and governance strengthening;

Despite its promise, scaling Nexus-aligned solarization faces operational and systemic challenges. Weak maintenance capacity, fragmented technical standards, insufficient budgets, and unclear roles risk undermining long-term functionality. Peace outcomes are not automatic and require intentional design - including conflict-sensitive assessments, stronger communication, and integration of social cohesion indicators in monitoring frameworks.

The paper includes recommendations to support long-term sustainability and conflict resilience. These include institutionalized preventive maintenance, ring-fenced operations and maintenance budgets, unified national technical standards, environmental performance indicators, and digital monitoring. Intentional design is required to support peace outcomes, through embedding conflict indicators at the outset, prioritizing community engagement and strengthening coordination platforms. Capacity building of authorities and multi-year, adaptive financing models are needed to support long-term sustainability and financial management.

Ultimately, the research demonstrates that solarization represents a strategic investment in resilience. When linked to institutional reform, community engagement, and peace-sensitive design, solar-powered water systems offer a replicable blueprint for Nexus programming in Lebanon. They provide immediate relief, build durable capacity within public institutions, and reduce sources of tension, helping to move the water sector from crisis-driven dependency toward sustainable, equitable service delivery.

INTRODUCTION

CONTEXT

Lebanon's water sector faces mounting challenges due to prolonged economic crisis, conflict, displacement and climate variability. Many communities struggle to access safe and reliable water due to damaged and degraded infrastructure and severe water scarcity. Their situation is exacerbated by chronic electricity shortages and dependence on costly diesel generators, which drive up the costs of pumping and transporting water through networks already under strain. Water shortages present significant risks for public health, food security and social cohesion, as hygiene deteriorates, agriculture production drops and competition for vital resources is heightened.

In this context, **the Nexus approach, integrating humanitarian, development and peace objectives**, offers a strategic framework for moving beyond short-term emergency measures towards resilience and sustainability. The Triple Nexus is particularly relevant for Lebanon, where humanitarian needs remain acute, development gaps persist, and community cohesion is strained by the ongoing impacts of conflict and displacement. Linking these dimensions ensures that water interventions not only provide immediate relief but also contribute to long-term recovery, institutional strengthening, and conflict prevention.

Against this backdrop, **solarization of water pumping stations has emerged as a promising entry point for operationalizing the Nexus in practice**. By reducing reliance on diesel, solarization lowers costs, mitigates greenhouse gas emissions, and enhances service continuity. At the same time, it reduces the financial burden on municipalities and water establishments, strengthens local governance, and alleviates social tensions associated with water scarcity and inequitable distribution.

This paper, based on research conducted by **GCE SARL**, documents **the case of solarizing two water pumping stations in South Lebanon, in a project supported by the Spanish Agency for International Development Cooperation (AECID)**, to assess their economic, environmental and social impacts, and to explore how such interventions can align with and advance Nexus principles. Findings from the two case studies are combined with stakeholder perspectives from local communities, municipalities, the South Lebanon Water Establishment (SLWE) and humanitarian partners, to demonstrate how solarized water infrastructure can serve as a model for bridging emergency relief, sustainable development, and peacebuilding outcomes in fragile contexts.

Solarization of Insariyeh pumping station

SOLARIZATION IN LEBANON

Lebanon has more than 1200 water and wastewater facilities, operated by four Regional Water Establishments. The country's Updated National Water Sector Strategy (NWSS 2020 / 2024) highlights the **high dependence of these facilities on grid power and diesel generators**, resulting in high operational costs and frequent service interruptions. Since 2019, escalating fuel prices and the near absence of electricity from the national grid have rendered many pumping and treatment stations inoperative for extended periods, threatening water security across communities.

Solarization of Insariyeh pumping station

In response, the Government of Lebanon, supported by development partners and donors, has begun **integrating renewable energy, particularly photovoltaic (PV) systems, into the water infrastructure** to improve energy resilience and service continuity. The solarization effort is aligned with Pillar 3 of the NWSS, which promotes shifting from energy-intensive to energy-saving systems as part of a broader water resource management approach. By early 2023, more than 140 facilities had been equipped with PV systems, demonstrating significant potential for energy savings.

Later that year, a national survey conducted under the EU-AFD Technical Assistance Programme evaluated approximately 580 electricity-subscribed water facilities for solarization potential, and revealed that **solar power can substantially reduce operating costs and energy dependency**.[1] Average energy savings were highest in the Bekaa and South Lebanon, and hybrid configurations (solar + grid or generator) were found to be most efficient, enabling continuous operation while maximizing PV utilization.

While the initial phase of solarization in Lebanon was driven by crisis response, the emerging focus is on long-term financial sustainability, aiming to reduce the Water Establishments' energy expenditures and strengthen the overall resilience of water service delivery. The solarization program forms a critical component of **the water sector's recovery and reform agenda**, supporting Sustainable Development Goals (SDG) 6 *(Clean Water and Sanitation)* and 7 *(Affordable and Clean Energy)*, as outlined in the updated NWSS.

[1] '*Short Note on the Potential of Solarization of Water-Related Infrastructures*', produced in the framework of the EU-AFD Technical Assistance Programme to Support Reforms in the Water and Wastewater Sectors in Lebanon, August 2023

RELEVANCE OF THE NEXUS APPROACH

The concept of the **Humanitarian-Development-Peace (HDP) Nexus** refers to the deliberate effort to link humanitarian assistance, development cooperation and peacebuilding into a coherent framework of action. It is grounded in the recognition that crises are increasingly protracted, multi-dimensional and interconnected, with populations facing urgent humanitarian needs, structural development gaps, and risks of instability or conflict. By promoting collective outcomes, multi-year planning, and cross-sectoral partnerships, **the Nexus seeks to transform aid delivery into an integrated process** that meets immediate needs and tackles the underlying causes of crises.

In Lebanon, this framework is particularly relevant, as multiple, overlapping crises have shown the limits of fragmented approaches. Emergency interventions such as water trucking or diesel subsidies offer temporary relief but do not address underlying fragilities. Development projects, though vital, often stall without stable financing or governance reforms. Meanwhile, **UNDP's Tension Monitoring System (TMS)**[2] reveals that water service interruptions and perceived inequality in distribution are consistent drivers of social tension, especially in the South and Mount Lebanon.

Solarization of water pumping stations embodies the shift from crisis-management to resilience-building. Solar power secures continuous water supply, lowering humanitarian pressure, advancing development by cutting costs and emissions, and contributing to peace by reducing fuel-related disputes and inequitable service gaps, and critically, by ensuring a sustainable power supply in times of conflict. In one intervention it delivers humanitarian relief, sustainable development, and social stability.

RESEARCH METHODOLOGY

This study, carried out by **GCE SARL**, applied a mixed-methods approach combining quantitative and qualitative data, collected between July and November 2025 from three complementary sources:

1) **Technical and financial project documentation**

Records were reviewed from solarization projects implemented by Action Against Hunger and partners, including capital expenditure, operating costs, diesel consumption, energy production logs, pump performance data, water supply metrics, greenhouse gas reduction estimates and runtime improvements. A case study focused on two specific sites, selected due to their representativeness in terms of system configuration, operational context, and institutional engagement.

2) **Field-based engagement**

Stakeholder engagement was conducted through key informant interviews (KIIs), questionnaires and community focus group discussions, involving stakeholders from the SLWE, municipalities, partner organizations and the community, aged 25 to 60 from both genders and all Lebanese nationals.

3) **Literature review**

A literature review covered documents and best practice on the Humanitarian–Development–Peace (HDP) Nexus, conflict sensitivity, and resilience programming to frame the proposed Nexus criteria.

[2] https://www.undp.org/lebanon/press-releases/tensions-monitoring-system-portal

CASE STUDY: SOLARIZATION OF WATER PUMPING STATIONS IN SOUTH LEBANON

Implemented by Action Against Hunger and GCE SARL with funding from the Spanish Development and Cooperation Agency (AECID), the project underpinning this study marks a significant step towards sustainable water management in a fragile and energy-insecure context. The initiative aimed to reduce dependency on diesel generators and grid electricity by **installing solarization to power a key borehole serving two villages in the South, Qaaqiyet el-Snoubar and Insariyeh–Adloun**. With its primary beneficiaries the SLWE and local community, the project set out to ensure continuous water delivery to local residence, improve resource efficiency and enhance resilience of public water infrastructure. Beyond the scope of the project, the intervention also has the potential to demonstrate a scalable solution for water-energy nexus challenges in rural Lebanon

PROJECT DESCRIPTION

The **Qaaqiyet el-Snoubar** installation uses more than 130 kWp of solar power spread across several rooftops and a ground-mounted structure. This design balances electrical efficiency, system redundancy and ease of maintenance. The PV system directly powers a submersible pump supported by an inverter, to optimize power conversion and minimize energy losses. The sizing of the components and panel orientation were designed to maximize the limited space available, ensure sufficient output even during seasonal solar variations, and to strike a balance between maximizing yield and reducing dust accumulation - a key consideration for the environment in South Lebanon.

Qaaqaiet El Sanawbar PS Solar Structure

Qaaqaiet El Sanawbar PS Entrance

The system now powers the main water pump directly from sunlight, helping to keep water flowing to households in the surrounding area. To strengthen operational reliability, dedicated panels were allocated to the control system and water treatment unit, ensuring that essential supervisory functions remain uninterrupted. Spare panels were delivered to the SLWE for future replacements, an important consideration given Lebanon's import restrictions and supply chain challenges.

The second site, in **Insariyé–Adloun**, responds to the urgent need for a more reliable water supply in a region heavily affected by electricity shortages and fuel crises. It comprises more than 220 kWp of solar capacity, powering a major pumping station that had suffered repeated shutdowns due to the national electricity crisis. The municipality allocated land for the site along a road near the pumping station, due to limited available roof and yard space. The solar array now supports a high-capacity water pump and ensures continuous operation of the station's treatment and control systems. As with the first site, spare panels were provided to help the Water Establishment maintain the system over time.

Insariyé-Adloun pumping station

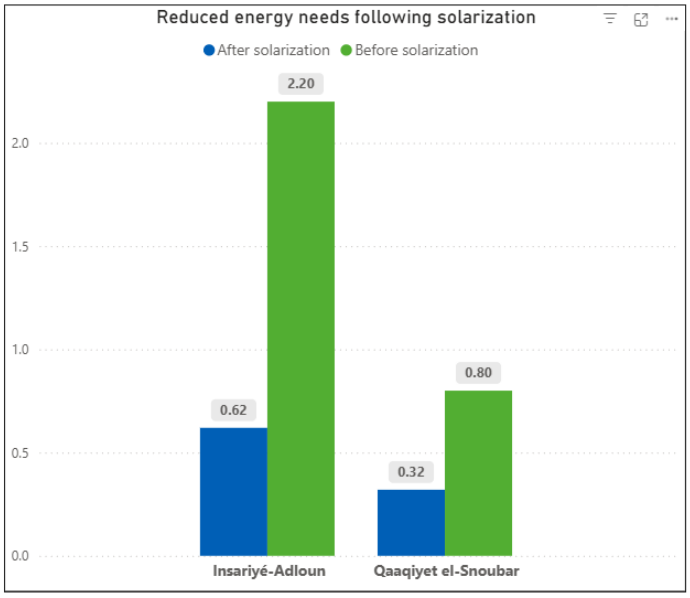
IMPACT ASSESSMENT

1) Economic impact

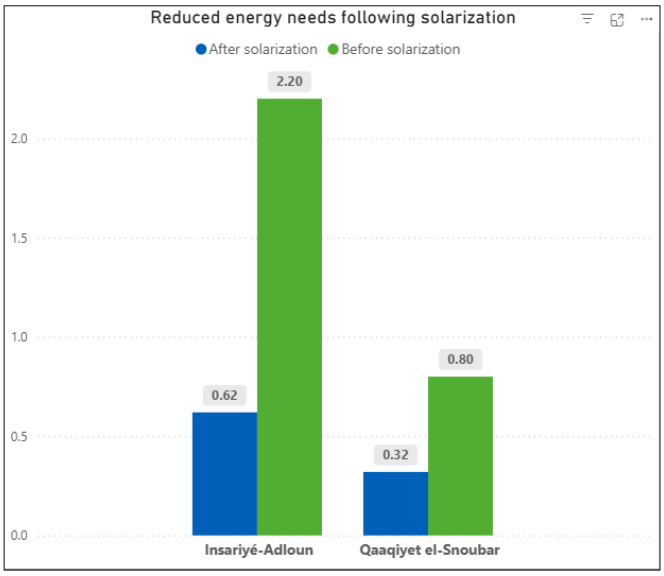
Before solarization, both the Qaaqiyet el-Snoubar and Insariyé–Adloun pumping stations depended almost entirely on expensive and unreliable energy sources. Frequent power cuts forced the SLWE to operate almost exclusively on generator power, which absorbed a large portion of the operational budget, left little room for infrastructure maintenance, and exposed the utility to vulnerability during fuel shortages and price spikes.

This dependency made water delivery extremely vulnerable to Lebanon's energy crisis, where even short fuel shortages could interrupt service for thousands of households. The cumulative effect at both sites was reduced institutional flexibility, deferred maintenance, and exposure to the volatility of fuel markets and exchange-rate fluctuations.

As indicated below, after solarization, **energy intensity was reduced by 60%**, reflecting higher system efficiency, as less energy is required to pump each cubic meter of water.

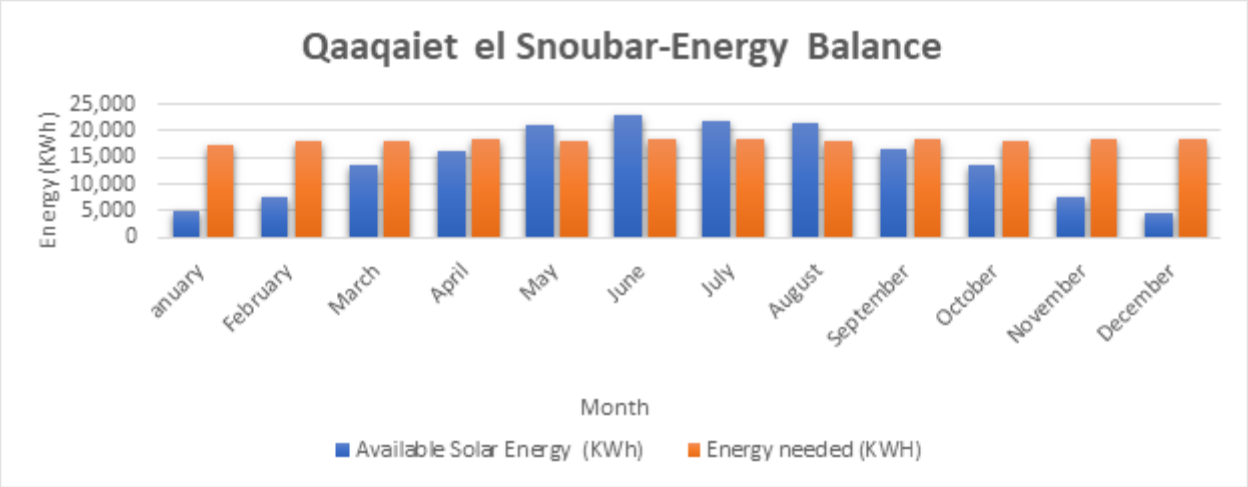


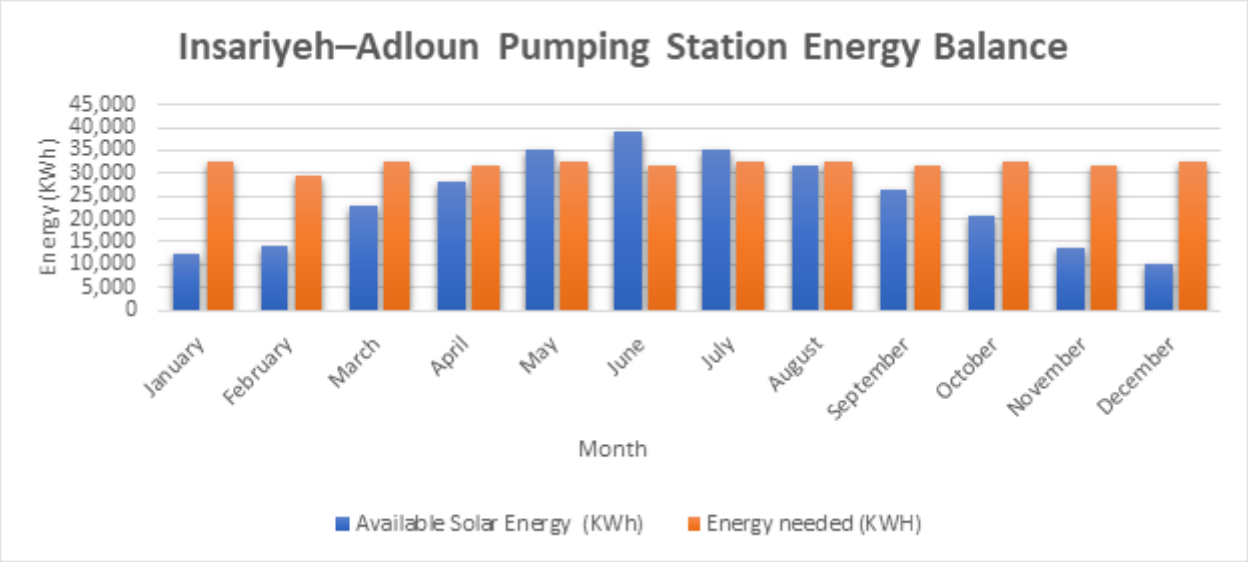
Solarization likewise reduced operating costs considerably, with **annual energy costs falling from approximately USD 78,000 to 33,000** at Qaaqiyet el-Snoubar, and at Insariyeh Adloun, **from over USD 100,000 to between USD 20,000 and USD 30,000**. Both systems were donor-funded, meaning SLWE benefited immediately from the operational savings without capital repayment obligations. Together, they generate annual savings exceeding USD 115,000, with **indicative payback periods of only about three years if self-financed**.



The **seasonal performance of the solar system highlights its role as both an energy source and a financial stabilizer**. During the summer months, the solar system was able to meet almost the entire pumping demand, reducing generator costs to a negligible level. In winter, when solar production naturally declines due to shorter days and weather conditions, SLWE still had to rely on diesel, though at significantly reduced levels compared to the pre-solarization baseline – demonstrating solarization's crucial role in buffering seasonal variations.

Overall, solarization has shifted SLWE from a fragile, fuel-dependent model to a more predictable and resilient financial footing. The resulting stability allows the utility to budget more effectively, reinvest in system repairs, and strengthen long-term service delivery.





Energy Balance: Monthly comparison of solar generation and total energy demand, illustrating seasonal variations in solar contribution and backup fuel needs

2) Institutional / Governance impact

By dramatically reducing operating costs, solarization has **strengthened the institutional health of SLWE at a time when Lebanon's public utilities face unprecedented pressure**. SLWE were able to redirect savings toward critical functions such as leak repair, metering, system upgrades, and staff support—activities that had long been deferred because diesel expenses consumed so much of the budget. The solar system ensured a minimum operational capacity even during extended grid outages or diesel shortages, enabling SLWE to maintain service continuity for thousands of residents. Reliable energy also means reliable pumping capacity, reducing service interruptions and lowering SLWE's dependence on short-term funding for emergency fuel.

At a governance level, **solarization has improved SLWE's credibility with communities,**

municipalities, and partners. The modernized infrastructure demonstrates the utility's ability to adopt sustainable and forward-looking solutions, even during national crisis conditions. Predictable energy supply enables more accurate budgeting and strengthens SLWE's operational planning, shifting the institution from reactive crisis management to proactive service delivery.

> ***"With lower fuel costs, SLWE can focus on improving the network instead of spending all its money on diesel. This gives us hope for better services."***
>
> ***SLWE staff member***

Taken together, the two projects demonstrate that solarization strengthens institutional resilience not merely by lowering costs, but by transforming how public utilities operate and are perceived. SLWE has moved from a reactive mode – constantly responding to energy shortages - to a proactive, planning-oriented model built on predictable costs and renewable supply. This structural stability supports better governance, improves accountability, and fosters partnerships with municipalities and donors.

3) Social impact

At the community level, **the economic impact of solarization translates into tangible relief for households**. With pumping operations becoming more reliable, families experience fewer interruptions in water service and are less dependent on costly trucked water, which has long been a financial burden, especially for poorer and rural households. At the same time, by easing SLWE's operating costs, solarization reduces the pressure to impose sudden tariff increases or enforce emergency service cuts, both of which typically provoke frustration and social tension. Pumping operations have become more consistent, providing households and farmers with dependable water for domestic use and irrigation.

Importantly, **the community also perceives the installation of solar panels as a visible and forward-looking investment** – a sign that public service providers and their partners are committed to lasting solutions rather than short-term fixes. The visible shift toward clean, self-sustaining energy has also enhanced public perception of the SLWE and municipal partners as responsive and capable institutions, fostering renewed confidence and civic trust.

During the recent conflict and resulting nationwide fuel shortages, these solarized systems played a critical role in preserving basic service continuity when diesel supply chains and grid electricity were disrupted. While neighboring communities struggled with water scarcity, the Qaaqiyet el-Snoubar and Insariyeh–Adloun stations continued operating partially or fully on solar power, safeguarding access to safe water for thousands of residents. This uninterrupted service became a tangible symbol of institutional reliability and collective resilience, mitigating panic, reducing social tension, and reinforcing solidarity within and between communities.

> ***"The solar system means fewer interruptions in service. Families are less stressed, and we receive fewer complaints at the municipality"***
>
> ***Municipal official, Qaaqiyet El-Snoubar***

Endline evidence from the two projects demonstrates measurable peace dividends linked to improved water service reliability. Quantitatively, **over two-thirds of surveyed households reported a reduction in water-related disputes** during peak demand periods, alongside an increase in willingness to rely on and pay for public water services, indicating improved trust in institutions. Qualitatively, community members and municipal stakeholders consistently reported fewer complaints, reduced mediation cases, and

improved perceptions of fairness in water distribution between host and refugee populations following solarization.

By stabilizing water access, reducing dependence on fuel-based rationing, and reinforcing the role of public service providers, the interventions helped mitigate localized tensions over scarce resources and strengthened social cohesion – confirming the peace dimension of solar-powered water infrastructure in fragile, mixed-community settings.

4) Environmental impact

The environmental benefits of solarization are substantial. By replacing diesel generators with clean solar energy, the Qaaqiyet el-Snoubar and Insariyé–Adloun systems **collectively avoid about 86 tons of CO_2 emissions annually**, as well as 206 kg of nitrous oxide and 161 kg of sulphur dioxide – pollutants that directly affect respiratory health and local air quality.

Solarization also **eliminates the significant noise pollution created by diesel generators**, which disturbs nearby residents and contributes to a general sense of environmental degradation. This can significantly affect daily life, particularly for communities already facing multiple stress factors. Residents experience a quieter and healthier environment, which in turn fosters greater trust and social support for renewable energy solutions. In this way, solarization goes beyond its technical and financial benefits to directly improve the quality of life for households living in proximity to the facility.

Solar power reduces Lebanon's dependence on imported diesel, easing pressure on foreign currency reserves and cutting the emissions and risks associated with transporting fuel. Less reliance on fuel trucks also lessens the burden on transport logistics, lowering risks of traffic congestion, road accidents, and associated emissions.

Beyond emissions, solarization promotes national resource efficiency and supports Lebanon's commitments under the updated National Water Sector Strategy and international climate frameworks. As a climate-positive intervention, it aligns environmental objectives with humanitarian and development goals – delivering cleaner air, improved public health, and more sustainable water service delivery.

Solarization of Insariyeh pumping station

Impact summary

Key Performance Indicator	Qaaqiyet el-Snoubar	Insariyeh–Adloun
Installed Capacity (kWp)	134.4	228.16
Pump Power (kW)	75	132
Annual Energy Savings (USD)	44,615	70,000 – 80,000
OPEX Reduction (%)	58%	70–80%
Payback Period (years)	3.25	3
CO_2 Reduction (tons/year)	16	70.41
NO_2 Reduction (kg/year)	44	162
SO_2 Reduction (kg/year)	53	108
Service Continuity (hours/day)	8–14	11–18
Outage Reduction (days/month)	20 → 1	6–8 → ≤2
Community Complaints	↓ >80%	↓ >80%
Institutional Trust Index (1–5)	2.5 → 4.0	2.5 → 4.0
Energy Autonomy (summer)	~85–90%	~85–90%

Overall impact in the context of the Nexus

The solarization of the Qaaqiyet el-Snoubar and Insariyeh–Adloun water pumping stations demonstrates how renewable energy can transform essential public services into resilient, sustainable, and peace-supportive infrastructure, with increased capacity, lower costs, reduced emissions, improved continuity and fewer complaints.

Collectively, these achievements illustrate the practical realization of the HDP Nexus within Lebanon's water sector. Solarization provided **humanitarian relief** by ensuring uninterrupted water supply, **advanced development** by enhancing financial and operational sustainability, and **promoted peace** by reducing community grievances and reinforcing institutional legitimacy. The case study stands as a replicable model for scaling solarization across the country – demonstrating that renewable energy is not merely a technical upgrade, but a strategic instrument for resilience, equity, and stability in fragile contexts.

STAKEHOLDER PERSPECTIVES

These technical findings were supported by targeted engagement with stakeholders from communities and municipalities, the SLWE, Action Against Hunger project staff and humanitarian partners (UNICEF and UNDP). The objective was to capture the lived experiences, perceptions, and institutional impacts of the solar interventions, providing a human-centered perspective on how solarization has affected water service delivery, governance, and community well-being.

SLWE

SLWE informants recognized in particular the improved output and continuity following the solarization, with **daily pumping nearly doubled**, and **service interruptions dropping from around seven days per month to just two**. They noted significant financial benefits of the intervention, with **annual operational expenses decreasing by two thirds**.

The utility noted that **the success of the two projects had driven broader sectoral improvements**: multiple new solar water projects are now under design or review, pending donor funding. To scale and sustain these gains, the SLWE noted a requirement for additional support in the form of **spare mechanical and electrical parts, SCADA installations for existing systems, and hybrid solar solutions** to power chlorination units at current solar pumping stations.

Municipalities and Community Representatives

Engagement with local representatives revealed several points of positive feedback, as the improved continuity in water supply translated into greater community cohesion and eased pressure on municipalities.

- **Improved Water Security:** Both solarization projects ensured continuous water availability and successfully met community water needs, even during periods of grid instability or increased demand.
- **Elimination of Water Complaints:** Before the projects, frequent water shortages and irregular supply were a persistent source of frustration for residents. After implementation, complaints related to water availability and distribution were eliminated, reflecting a significant improvement in service quality and reliability.

Qaaqaiet El Sanawbar Solar System- roof 2

- **Significant Reduction in Operational Burden:** The transition from diesel-powered pumping to solar energy drastically lowered operational expenses, and removed the constant challenge of securing and transporting fuel to run generators during power outages. This relieved municipalities from financial pressure and logistical complications, allowing them to focus on service delivery rather than emergency fuel procurement.
- **Budget Reallocation to Community Development:** The savings achieved from reduced fuel consumption and lower operation costs enabled municipalities to redirect a portion of funds toward other essential development initiatives. These included street lighting projects, wastewater treatment plant (WWTP) improvements, planting and landscaping initiatives, and various infrastructure enhancements. This reallocation amplified the broader community benefits of the solarization projects beyond the water sector.
- **Wider Socioeconomic Impact:** The improved water services and efficient use of resources contributed to better living conditions, enhanced public trust in local authorities, and stronger social cohesion. Communities also expressed increased support for renewable energy

solutions, encouraging future sustainability-focused projects across different sectors.

Humanitarian Partners (Action Against Hunger, UNICEF, UNDP)

All agencies recognized the value of solarization as a humanitarian necessity that has evolved into a development-enabling intervention, stabilizing water supply amid Lebanon's prolonged energy crisis, with significant potential to support peacebuilding objectives through the reduction of social tensions.

1. Nexus Positioning and Impact

- Action Against Hunger highlighted the strong **humanitarian impact** of improved water availability, reduced dependency on diesel, and strengthened efficiency in operations and maintenance.
- Action Against Hunger and UNICEF both noted the **development relevance** of the long system lifespans (20–25 years) and significant reductions in operational costs and energy dependency. UNICEF also integrates CO_2-reduction and energy-savings monitoring, adding a **climate co-benefit dimension**.
- UNDP, drawing on evidence from their Tension Monitoring System (TMS), stressed that water reliability is closely tied to local tensions, making **solarization relevant for peace dividends** when conflict-sensitive approaches are applied. They stressed the need for equitable distribution, inclusive engagement, and integration of validated conflict indicators.

2. Implementation Approaches and Governance

All agencies underscored the importance of **participatory or institutional coordination mechanisms**:

- Action Against Hunger designed its projects through consultations with SLWE, municipalities, and communities, reporting no conflict incidents during implementation.
- UNICEF supports the governance dimension through co-leading the national solarization task force with the Ministry of Energy and Water and AFD, while strengthening Water Establishments through PV maintenance units and training.

4. Key Challenges Identified

Across the three agencies, several systemic constraints emerged:

- **Technical and operational**: land limitations for panel installation, high SCADA costs, fragmented technical standards (Action Against Hunger); weak operator capacity and inconsistent data-sharing (UNICEF).
- **Institutional**: low tariffs undermining cost recovery (UNICEF), mechanical vulnerabilities persisting in several stations (Action Against Hunger).
- **Peace and conflict sensitivity**: lack of explicit conflict-sensitivity frameworks and peace indicators across most solarization initiatives (Action Against Hunger, UNICEF), despite water being a known driver of tensions (UNDP/TMS).

OPERATIONALISING THE NEXUS

PROPOSED CRITERIA FOR NEXUS-ALIGNED INTERVENTIONS

International practice shows that not every project that saves lives or improves services automatically qualifies as "Nexus-aligned". To meet this definition, interventions must go beyond addressing urgent needs to also build systems, strengthen resilience, and reduce risks of future crises.

Based on the findings of this research, **four criteria are proposed to define Nexus-aligned interventions**. These draw on global benchmarks and are contextualized for Lebanon's water–energy–peace nexus, particularly through the lens of solarized water pumping systems.

1. Long-Term Impact (>2 years)

International benchmark: The OECD Development Assistance Committee (OECD-DAC) framework and the UN's "New Way of Working" (NWOW) emphasize that Nexus programming must be planned on a **multi-year horizon**, prioritizing **sustainability**, **resilience**, and **risk reduction** rather than short-term outputs.

Application to water solarization:

- Solar systems should have a technical lifespan of **at least 10–15 years** for panels, with defined replacement cycles for batteries, inverters, and pumps.
- Water Establishments and municipalities must **integrate operation and maintenance (O&M) and spare parts into their** annual budgets **for a minimum of** three years beyond donor support.
- **Continuity of water service** (daily hours, reduction in outages) **should be tracked year-on-year** to ensure reliability.
- **Cost savings** from reduced diesel use should be **documented and reallocated** toward community services such as waste collection, street lighting, or health.

Example indicator: Percentage of annual O&M cost covered by local funds after donor exit.

2. Integration of Humanitarian, Development, and Peace Objectives

International benchmark: The 2016 World Humanitarian Summit and the UN Joint Steering Committee on the Humanitarian–Development–Peace (HDP) Nexus define *Collective Outcomes* as measurable results that **reduce needs, risks, and vulnerabilities** through joint action among humanitarian, development, and peace actors.

Application to water solarization:

- **Humanitarian dimension:** Continuous and equitable water access preserves lives, health, and dignity.
- **Development dimension:** Reduced energy expenditure enhances the financial viability of utilities and improves institutional efficiency.
- **Peace dimension:** Transparent and equitable service delivery reduces community tensions and strengthens trust in public institutions.
- Projects should **explicitly define, measure, and report** results across all three dimensions (e.g., household satisfaction, municipal cost recovery, complaint reduction), with particular focus on peacebuilding components, given these are not currently embedded in project designs as standard.

Example indicator: Number of collective outcomes monitored across H–D–P dimensions.

3. Conflict-Sensitive and Resilience-Oriented Design

International benchmark: The OECD-DAC guidance provides evaluation and policy guidance for peacebuilding activities in conflict settings. Similarly, the foundational Do No Harm principle ensures that interventions minimize negative impacts on the local conflict dynamics.

Application to water solarization:

- Conduct **context and conflict sensitivity analyses**, mapping *Dividers and Connectors* (e.g., between refugee and host groups or across neighborhoods with unequal service).
- Ensure **transparent communication** about project objectives, service hours, and tariff implications to prevent misinformation and exclusion.
- Design systems to **withstand shocks** – fuel shortages, grid failures, drought – thus strengthening resilience.
- **Solarization inherently reduces vulnerability** to energy crises by providing autonomous, renewable power.
- Integrate **risk mitigation and grievance redress** mechanisms accessible to all user groups.

Example indicator: Percentage of surveyed households reporting fewer water-related disputes since solarization.

4. Community Engagement and Governance Strengthening

International benchmark: Multiple agreed international frameworks, including the UN New Ways of Working and the EU Council guidance on local ownership, underline that sustainable Nexus interventions must build the capacity of local institutions and empower communities, rather than substitute their roles.

Application to water solarization:

- Ensure **active participation of municipalities, water establishments, and local communities** in project planning, implementation, and monitoring.
- Provide **technical and financial training** to municipal and SLWE staff on maintenance, monitoring, and budget planning.
- Establish **community consultation mechanisms** such as public hearings, participatory budgeting sessions, and grievance redress channels.
- Introduce **transparency tools** (dashboards, data-sharing platforms, or community scorecards) to allow citizens to track improvements and hold institutions accountable.
- Strengthen feedback loops to ensure community input leads to concrete adjustments in service delivery.

Example indicator: Percentage of households reporting that they were consulted before or after project implementation.

INTEGRATING THE PEACE DIMENSION

As highlighted in the social impact of the case study, solarization presents a compelling example of how a project can support all elements of the HDP Nexus. However, while the humanitarian and development dimensions are increasingly mainstreamed in Lebanon's water sector, the peace pillar remains under-operationalized. Yet, as reflected in the UNDP TMS findings (2023–2025), service disruption and perceived inequality in water access are persistent drivers of local tension. Embedding peace and conflict sensitivity within sectoral programming is therefore essential to ensure that infrastructure interventions:

Qaaqaiet El Sanawbar Solar System- roof 1

- **Do no harm**, by preventing unequal service distribution that may fuel resentment;
- **Strengthen social cohesion**, by fostering joint management between municipalities, Water Establishments, and users; and
- **Reinforce institutional legitimacy**, restoring public trust in water governance.

This approach aligns with the **UNDP Stabilization and Social Cohesion Strategy for Lebanon (2022–2025)** and the National Water Sector Strategy 2024 (NWSS 2024), which together emphasize that equitable, reliable water services are foundational to peace, stability, and resilience.

To operationalize the peace dimension, conflict-sensitive thinking must be **institutionalized at every phase** of the project cycle:

Project Phase	Peace/Social Cohesion Entry Points
Design	Conduct conflict and stakeholder mapping to identify potential tensions related to resource allocation, land use, or service coverage. Ensure inclusive

	planning by engaging municipalities, Water Establishments, and community representatives.
Implementation	Establish communication and grievance mechanisms to manage complaints and reinforce transparency. Promote local labor participation to increase ownership and reduce resentment.
Monitoring & Evaluation	Integrate peace/conflict indicators into project logframes. Regularly assess how the intervention affects trust, cooperation, and community satisfaction. Use participatory monitoring tools (e.g., community scorecards).
Sustainability Phase	Strengthen local governance capacities (municipal and Water Establishments) to manage operations collaboratively and sustain service delivery equitably.

Integrating peace into the Nexus approach aligns with national and international frameworks such as the National Water Sector Strategy 2024, the Lebanon Response Plan (LRP), and the UNDP Stabilization and Social Cohesion Programme. These frameworks emphasize transparent governance, citizen trust, and equitable service delivery as foundations for stability. Evidence from the TMS shows that communities benefiting from consistent and transparent water services report lower tension levels and greater institutional trust.

CHALLENGES, LESSONS LEARNED AND RECOMMENDATIONS

CHALLENGES AND LESSONS LEARNED

1) Technical and Maintenance Issues

In the case studies examined, the distributed layout of the solar installations increased the need for careful monitoring, cleaning, and periodic technical inspections. In some cases, maintenance responsibilities were not clearly defined between SLWE staff, contractors, and municipalities, creating gaps in response time when faults occurred. A further challenge lay in ensuring the timely replacement of inverters and pumps, which have shorter lifespans than solar panels.

- **Lesson learned:** technical sustainability requires not only the initial engineering design but also a **clear maintenance framework, dedicated budgets, and trained local staff** to ensure continuity beyond donor support.

2) Financial Sustainability

Although donor funding covered the upfront capital costs, **long-term financial sustainability** remains a key concern. Water Establishments operate under severe budgetary constraints, often unable to fully recover costs through tariffs. Without reliable revenue streams, allocating funds for O&M, spare parts, and eventual system upgrades remains a challenge, and performance may decline unless financial

mechanisms are embedded.

- **Lesson learned:** interventions must include **financial sustainability strategies**, such as ring-fencing part of the savings from diesel costs, exploring tariff adjustments, or linking to municipal development budgets to secure resources for ongoing maintenance and system renewal.

3) Coordination Gaps Across Actors

The projects involved multiple stakeholders donors, SLWE, municipalities, contractors, and local communities, and while collaboration was generally positive, **coordination gaps** emerged during planning and implementation. In some cases, municipalities were not fully engaged in decision-making, or community consultations were limited to late project stages. Similarly, reporting and accountability mechanisms between implementing partners and SLWE were sometimes fragmented, limiting efficiency.

- **Lesson learned:** successful Nexus interventions require **early and continuous coordination**, with all actors engaged in transparent planning, joint monitoring, and regular communication platforms to ensure alignment and ownership.

4) Political and Security Risks

In Lebanon's fragile political and economic context, even technically sound projects face **risks of politicization**. Community perceptions of favoritism in site selection, allocation of resources, or tariff implications can undermine trust. Political actors may also attempt to claim credit for donor-funded projects, complicating governance dynamics. In addition, access to aid is sometimes constrained by local power structures, with risks that benefits may not be distributed equitably across communities.

Another critical factor is the **risk of war or other armed conflict**, which can disrupt service delivery, damage infrastructure, and undermine the sustainability of investments. In frontline or high-risk areas, solar installations may be exposed to physical damage or restricted access, delaying maintenance and reducing community confidence.

- **Lesson learned:** to mitigate these risks, projects must adopt **conflict-sensitive and contingency-based approaches**, including transparent criteria for site selection, clear communication with communities, the establishment of grievance mechanisms, and the integration of **risk preparedness plans** (e.g., securing spare parts, decentralizing critical equipment, or designing flexible O&M models that can function under crisis conditions).

RECOMMENDATIONS

A number of specific actions can be taken by **humanitarian programmers and donors** to ensure projects meet the humanitarian, development and peace requirements of vulnerable communities, taking the solarization case study as an example:

1) **Dedicate resources to maintain interventions sustainably beyond the scope of emergency response.** For solarization projects, institutionalize preventive maintenance for installations and establish ring-fenced operations and maintenance funding using a portion of fuel-cost savings. Integrate mechanical rehabilitation (pumps, valves, leak repairs, pressure management) to ensure full performance gains.

2) **Work towards national, unified standards to provide consistency in future interventions.** For solar water systems, this involves harmonizing equipment, spare parts, and monitoring requirements.

3) **Incorporate digital monitoring tools where possible to support resilience in crisis situations.** Wherever possible, solar installations in Lebanon should include SCADA-ready or simplified digital monitoring tools, linked to Ministry of Energy and Water's national data hub for real-time operational oversight.

4) **Develop crisis preparedness procedures and risk management protocols for conflict and disaster scenarios.** Solarization and similar projects should account for accessible spare sparts storage, repair teams, and contingency plans for access disruption. Project selection criteria can also be enhanced to factor in vulnerability, sustainability, equity, and conflict drivers

5) **Strengthen conflict-sensitive design by integrating peace and social cohesion indicators from the outset**. For solarization projects this should include reference to the UNDP Tensions Monitoring Systems data and municipal risk profiles, as well as Do No Harm principles and community engagement protocols.

6) **Prioritize community involvement and local stakeholder engagement to support sustainability and participatory governance.** This includes regular engagement of municipalities, committees, and community representatives in decision-making and grievance management, while integrating structured feedback loops to maintain community engagement. For solar projects, technical and Nexus approaches can be aligned through **strengthening national coordination platforms**, including the Solarization Task Force and WASH Working Group.

7) Integrate environmental monitoring within programming wherever possible, to increase resilience and manage climate impacts. Solar projects should include systematic tracking of emissions reduction and other environmental performance indicators.

8) Develop a national roadmap, incorporating long-term capacity building and coaching for local operators, to guide scale-up, standardize designs, improve crisis preparedness, and ensure long-term sustainability. Solarization projects would benefit from a National Solar Water Nexus Roadmap, with on-the-job support for water establishments and municipal operators on preventative maintenance, digital tools and financial planning.

9) **Adopt multi-year, adaptive financing models** to ensure appropriate allocation of funds over time. For solar, these should be aligned with the National Water Sector Strategy 2024 and National Renewable Energy Action Plan, including cost-sharing mechanisms that reinvest solar savings.