AMERICAN UNIVERSITY OF BEIRUT

REGULATING THE RESIDENTIAL SOLAR BOOM IN LEBANON: POLICY FRAMEWORKS AND STRATEGIC INITIATIVES FOR PHOTOVOLTAIC TRANSITION

by
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ABSTRACT
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Title: Regulating the Residential Solar Boom in Lebanon: Policy Frameworks and Strategic Initiatives for Photovoltaic Transition

The economic and financial crisis in Lebanon that started in 2019 has exacerbated the shortfalls of the Lebanese energy sector. This is due to the emerging inability to continue funding the imports of fuel oil, the main component that the sector relies on, with hard currencies. Amidst increased and critical power outages, Lebanon has witnessed a significantly observable boom in the installations of distributed solar PV to achieve independence from the failing fuel-powered grids, especially in the residential sector. Installations, however, have been chaotic and unregulated, with the government not playing its role in instating the proper legislative, institutional, and policy environment for these installations to take this transition in a strategic approach. With the current trend, the Lebanese energy sector might be headed in a direction that requires even more reforms down the line. This study aims to assess both the active and dormant laws and institutes that are responsible for regulating distributed solar PV installations and to perform a comparative analysis with other countries across the globe to draw policy recommendations for Lebanon. This study will offer a better understanding of what needs to be done in Lebanon in the upcoming years and aid in instating relevant reforms and policy recommendations.

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ABBREVIATIONS

Full Form	Abbreviation
Direct Normal Irradiation	DNI
Global Horizontal Index	GHI
International Renewable Energy Agency	IRENA
Electricity Regulatory Authority	ERA
Independent Power Producers	IPPs
Électricité du Liban	EDL
Ministry of Energy and Water	MEW
Ministry of Finance	MoF
Council of Ministers	CoM
Lebanese Center for Energy Conservation	LCEC
Renewable Energy	RE
Decentralized Renewable Energy Law	DRE
Nationally Determined Contributions	NDC
Ministry of Interior and Municipalities	MOIM
Banque de l'Habitat	BDH
Single-Family Solar Homes Program	SASH
California Solar Initiative	CSI
Electric Vehicle	EV
Renewable Energy Sources Act	EEG
National Electrical Code	NEC
North American Board of Certified Energy Practitioners	NABCEP
Underwriters Laboratory	UL
Occupational Safety and Health Administration	OSHA
Limited Renewable Energy Technician	LRT
Sales and Operations Planning	S&OP
China's National Energy Administration	NEA
Enterprise Resource Planning	ERP
International Residential Code	IRC
International Building Code	IBC
per square foot	psf
Solar Energy Awareness and Education Program	SEEP
Lebanese Solar Financing and Incentive Program	LSFIP
Lebanese Solar Quality and Training Entity	LSQTE

Interstate Renewable Energy Council	IREC
National Electric Code	NEC
Lebanese Solar Supply Chain Optimization Program	LSSCOP

CHAPTER I

INTRODUCTION

A. Background Information on the Energy Crisis in Lebanon

1. The Way the System Functioned

Fossil fuels are the basic foundation of Lebanon's energy system. They are used as the main pillar for electricity production, transportation, factories, heating, and other basic needs. In fact, 95% of Lebanese primary energy supply in 2020 came from fossil fuels [1]. Back in the day, this used to work, especially since Lebanon used to import crude oil to its refineries where it produced its own fuels. After the 1975-1990 civil war, refineries were shut down, the import infrastructure was destroyed, and the whole grid was damaged and deemed no longer reliable [2]. Supply was no longer matching with demand, and this persisted until 2018 marked a supply-demand gap of 1500MW gap [3].

Many reasons left this dire situation untreated. Politicians found this an opportunity to profit from the various electricity purchase agreements that tried to cover demand at unjustifiable high costs (i.e. Turkish power barges [4]). They also backed and formed fuel-importing cartels to control prices, and they backed the private generator owners to benefit from them [5, 6]. In fact, fuel imports into Lebanon are handled by an oligopoly of 13 companies with links to politicians and sectarian leaders who make up the country's governing structure[6]. In 2018, the total commercial market size (subscription-based) of this generator market was estimated at $1.1 billion, serving 1.08 million customers whose electricity purchase is estimated at 4 TWh [7]. This has all led to a chaotic energy environment with conflicting interests and weakened state control [8].

Moreover, Lebanon's vertically integrated public power utility, Electricité du Liban (EDL), has always had the exclusive right of public electricity generation (except for hydroelectric concessions), transmission, and distribution in Lebanon, and has been operating at a loss [9]. EDL prices were set after the civil war in 1994 at US¢ 9.5 /kWh, when tariffs were at $23 per barrel [9], and were never changed until very recently (November 2022[1] [10]). This was only covering 45% of the operational costs averaging at around US¢ 20 /kWh (US¢ 15 generations costs + US¢ 5 transmission and distribution losses) [11]. To make matters worse, the hyperinflation that started in 2019 led the US¢ 9.5 tariff, that was still collected at the pre-inflation rate of 1,500 L.L/$, to have a real worth of less than US¢ 1 per kilowatt hour (kWh), causing even further losses [9]. In fact, this difference between the cost of generation and the tariffs has always been subsidized by state finances, with $40 billion transferred to EDL for subsidies from 1992 to 2018, a value representing 45% of the country's public debt [11]. This was accompanied by rationing of feed-in hours down to 6-22 hours across different regions.

2. *The System Collapse*

The Lebanese have always countered this rationing by subscribing to the private generators sector, with subscriptions being a common business-as usual-for everyone.

[1] In November 2022, EDL announced that it will start calculating the electricity bill in dollars but collecting each month in Lebanese lira according to the dollar-lira exchange rate set by Banque du Liban's Sayrafa platform. The first bill on new tariffs were collected in February 2023

These private generators relied heavily on oil cartels, which got foreign currency credits from the central bank (BDL) to import fuel [6].

As the currency started collapsing in 2019, BDL kept on subsidizing the imports of fuel and other necessities at the 1,500 L.L/$ official exchange rate, causing the hemorrhage of foreign currency from the central bank and the fall of its reserves from $40 billion in 2016 to less than $13 billion by mid-2021 [2]). This led to the gradual removal of subsidies and the subsequent inability to import fuels for both EDL and oil cartels. Hoarding and scarcity of fuel started showing, and the system collapsed. By 2022, EDL's electricity production capacity dwindled down to 229 MW, compared to 1711MW in 2019. This has led to longer-lasting power cuts. In 2022, electricity supplied by EDL averaged 1 to 2 hours/day [12].

Private generators followed suit as well, keeping the Lebanese people in blackouts for long hours [9]. This severely disrupted their daily lives, forbidding them from consistent refrigeration, heating, cooling, water pumping, cooking, and receiving basic services like telecommunications and healthcare, etc.

B. The Emergence of Solar PV as a Potential Solution

When the rations started, an initial solution trend in the summer of 2021 was installing private household generators, which were fed with fuel bought from the black market's foreign currencies. This was not sustainable as it required a lot of operational costs, forcing consumers to pay over US¢ 31/kWh [9].

With Lebanon experiencing one of the world's most severe financial crises, the overpricing led to lowered accessibility to electricity among the Lebanese population. Lebanese residents and businesses were forced to find alternative sources of energy.

The necessity for reliable and affordable electricity pushed people towards solar energy, as it became the cheapest and most convenient option available [13]. Soon after, a boom in the installation of household solar energy systems was observed, after it has been slowly growing since the beginning of 2021. By June 2023, Lebanon had seen a significant increase in solar capacity, reaching 1000 MW, which is equivalent to 700 MW of conventional electricity [14]. This sudden growth can reap many benefits for the Lebanese energy sector financially, environmentally, and politically, if properly guided and regulated by authorities [15].

C. The Need for Regulation and Policy for Distributed Solar PV in Lebanon

The energy crisis in Lebanon, characterized by persistent power outages, has heightened the urgency for establishing better regulations and policies specifically tailored to residential solar photovoltaic (PV) installations. The nascent stage of solar PV development in the country offers significant room for growth, making it crucial to steer this expansion with well-defined regulations. Currently, the lack of proper regulation and oversight has led to chaotic and unregulated installations, presenting various risks including safety hazards, inefficiencies, and market exploitation. As such, implementing robust regulations and policies is vital to ensure the safe, efficient, and sustainable growth of the solar PV market, directly impacting the journeys of the end-user, contractor, and regulator. A strong regulatory framework is essential to balance these interests, fostering a sustainable, efficient, and fair solar PV market.

1. The End-User Perspective

For end-users, primarily homeowners and small business proprietors, regulations serve as safeguards that ensure the safety, efficiency, and economic viability of their solar PV systems. Effective regulations are crucial in guaranteeing that installations are safe, perform optimally, and represent a sound economic investment. Furthermore, they provide protection against fraudulent practices, enhancing the overall quality of life and environmental well-being.

a. <u>Safety and Efficiency</u>

Specific guidelines and standards set by regulations ensure safe and efficient installations, outlining the technical requirements, safety measures, and electrical standards that need adherence during the installation process. These regulations are crucial in preventing substandard installations, ensuring compliance with safety codes, and minimizing potential hazards.

b. <u>Consumer Protection and Transparency</u>

Regulations enhance consumer protection by promoting transparency and reliability in the solar PV market. Establishing certification processes, quality control measures, and warranties are vital steps the Lebanese government can take to protect consumers from subpar installations or fraudulent practices.

c. <u>Streamlined Grid Integration</u>

Regulations are essential in facilitating the integration of residential PV systems into the existing electricity infrastructure. They help address issues related to net metering, feed-in tariffs, interconnection standards, and grid stability, ensuring a more reliable and resilient electricity supply.

2. The Contractor Perspective

Contractors are integral to the solar PV sector, and regulations are paramount in dictating the quality and safety of installations. A well-regulated market ensures fair competition, promotes professional development, and safeguards workers' rights, all while contributing to the industry's overall growth and stability.

a. Professional Growth

Regulations mandate training and certification, enhancing the skills and credibility of contractors. This leads to higher quality installations, fostering professional development and increasing business opportunities.

b. Worker Protection

Safety standards and best practices specified in regulations protect workers, ensuring safe installation and maintenance of solar PV systems. This minimizes accidents and improves both job satisfaction and industry reputation.

c. Streamlining and Smoothing Operations

Regulations provide clear operational guidelines, reducing bureaucratic hurdles and improving efficiency. This helps contractors in planning, executing, and managing solar PV projects more effectively.

3. The Regulator Perspective

For regulators, the implementation of regulations is about more than just oversight, it is about steering the solar PV sector towards national objectives of sustainability, economic growth, and energy independence. Regulations serve as critical tools for ensuring public safety, fostering sustainable development, and guiding the sector in a manner that aligns with Lebanon's broader goals.

a. Sustainability and Environmental Responsibility

Regulations facilitate the adoption of solar PV systems, and thus align with Lebanon's commitment to reducing greenhouse gas emissions and promoting a greener future.

b. Economic Growth and Energy Independence

Through regulations, the government can stimulate growth in the solar sector, encouraging innovation, job creation, and reducing reliance on imported fuels.

c. Enhanced Oversight and Data Governance

Regulations enable better tracking of installations and energy production, leading to improved fee collection, data governance, and informed policymaking, ensuring the sector's integrity and success.

The implementation of comprehensive and effective regulations for residential solar PV installations in Lebanon is imperative. By addressing the specific needs and contributions of end-users, contractors, and regulators, Lebanon can foster a balanced, efficient, and fair solar energy sector. This approach ensures transparency for consumers, smoother operations for contractors, and enhanced oversight for regulators, leading to a resilient and environmentally friendly energy future. Through these concerted efforts, Lebanon can harness the full potential of solar PV technology, contributing to national energy security and environmental objectives.

D. Purpose and Potential Impact of the Study

This study addresses the critical need for a robust regulatory framework in Lebanon's solar photovoltaic (PV) sector. Given the country's significant solar potential and the pressing energy challenges it faces, there is a timely opportunity to harness solar energy for sustainable growth. This research seeks to lay the groundwork for this endeavour by examining the regulatory landscape, identifying the gaps, and proposing actionable solutions.

The primary purpose of this study is to provide a comprehensive understanding of the current solar PV regulatory environment in Lebanon and benchmark it against global best practices. By doing so, the study aims to identify and articulate effective strategies and policies that could significantly enhance the adoption and efficient use of solar PV technology in Lebanon, thus supporting the country's energy transition and economic development.

To achieve its objectives, the study will critically analyze existing laws and regulations related to solar PV within Lebanon and compare them with successful international models. It will utilize a combination of comprehensive literature review and case study analysis of selected benchmark countries to understand different regulatory environments, their successes, and their applicability in the Lebanese context. The study will shed light on the historical development, current status, and future prospects of solar PV in Lebanon, highlighting both opportunities and challenges.

Several significant contributions are achieved by this study. Firstly, it will enhance the understanding of Lebanon's solar PV potential and the regulatory adjustments required to tap into this resource effectively. Secondly, by offering a set of tailored recommendations, it will serve as a guide for policymakers, industry stakeholders, and regulators to develop and implement more effective solar PV regulations. Lastly, the study aims to stimulate a broader dialogue on sustainable energy practices in Lebanon, contributing to the country's energy security, environmental sustainability, and economic resilience.

CHAPTER II

METHODOLOGY

A. Research Design and Methodology

The methodology of this thesis is designed to provide a comprehensive and systematic exploration of the solar PV regulatory framework in Lebanon through levelling it against advanced international practices. The study employs a qualitative approach, emphasizing depth and contextual understanding over quantitative breadth. The primary data collection methods include a comprehensive literature review and a case study analysis.

A literature review is presented to construct a foundational understanding of the solar PV sector and its regulations. This review will encompass academic journals, industry reports, policy documents, and other relevant publications. It will provide a wide-ranging overview of existing knowledge and identify both established practices and emerging trends in solar PV regulation.

Following the literature review, the study will conduct a case study analysis of selected benchmark case studies. These case studies will offer an in-depth view of specific policies, programs, and initiatives, along with their outcomes. By delving into the experiences of these countries, the study aims to uncover the nuances of successful regulation and the pitfalls of less effective approaches. The comparative nature of this analysis will highlight similarities and differences, distilling key insights and success factors that are relevant to Lebanon.

The findings from both the literature review and case study analysis will inform a qualitative analysis focused on the regulatory frameworks of the benchmark countries.

This analysis will identify common themes, best practices, challenges, and lessons learned. The goal is to synthesize these insights into a coherent understanding that can inform policy directions and recommendations for Lebanon.

Drawing from this rich qualitative exploration, the study will then develop a set of tailored initiatives and policy recommendations. These will be designed to address the specific challenges and gaps identified in Lebanon's current solar PV regulatory landscape. Finally, the study will propose a strategic roadmap for the implementation of these policies, outlining a path forward that balances immediate needs with long-term sustainability goals.

B. Limitations and Assumptions of the Study

This study, while comprehensive, is subject to certain limitations and assumptions that must be acknowledged. A primary limitation is the reliance on existing literature, which may vary in quality and depth. The study maximizes efficiency by focusing on reputable sources and prioritizing official publications and peer-reviewed academic journals. However, the variability in literature quality means that some nuances or recent developments may be underrepresented. The implications of this limitation are carefully considered, ensuring that conclusions and recommendations remain grounded and robust.

Another limitation is the study's focus on residential solar PV regulations. While this focus allows for depth and specificity, it also means that findings may not be directly transferable to other sectors or scales of solar PV installations. The implications here are a more targeted set of recommendations, specifically suited to the residential context but potentially less applicable to commercial or industrial solar PV scenarios.

In terms of assumptions, the study proceeds with the understanding that the information obtained from the literature review and case studies accurately represents the current state of solar PV regulations in the selected benchmark countries. This assumption is critical to deriving valid insights and recommendations. However, the dynamic nature of policy and regulation means that some information may become outdated or may not fully capture recent shifts. The study will remain cognizant of this, aiming to incorporate the most current data and acknowledging the temporal context of its sources.

By transparently addressing these limitations and assumptions, the study ensures that its findings are presented with integrity and clarity, providing valuable insights for policymakers, industry stakeholders, and the broader community interested in the sustainable development of the solar PV sector in Lebanon.

CHAPTER III

LITERATURE REVIEW

A. Overview of the Global Solar PV Industry and its Growth

The global solar photovoltaic (PV) industry has continued to experience significant growth, driven by technological advancements, cost reductions, environmental considerations, and policy support. As of 2022, the global installed capacity of solar PV reached approximately 1.2 terawatts (TW), almost double that recorded in 2019 at 630 MW [16]. At this growth rate, global solar PV installations are expected to reach 2,546.5 TWh by 2028, exhibiting a compound annual growth rate (CAGR) of 16.4% during 2023-2028 [17]. This growth signifies the increasing reliance on solar PV, which accounted for nearly 4.6% of global electricity generation in 2022 [18].

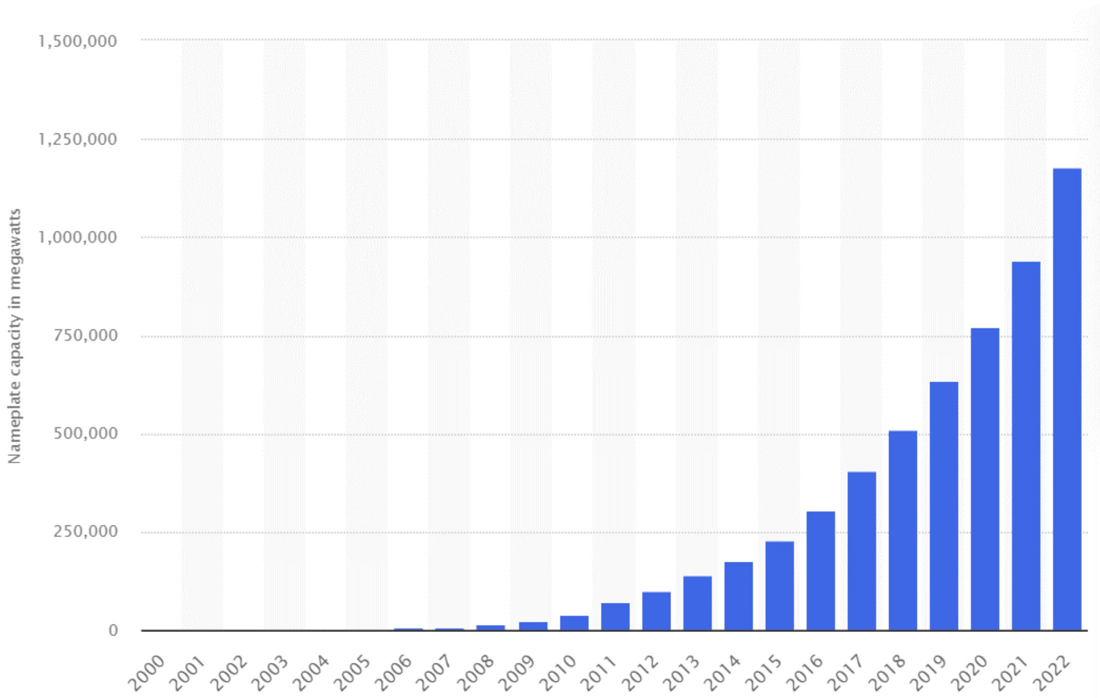


Figure 1: Cumulative installed solar PV capacity worldwide from 2000 to 2022 [16]

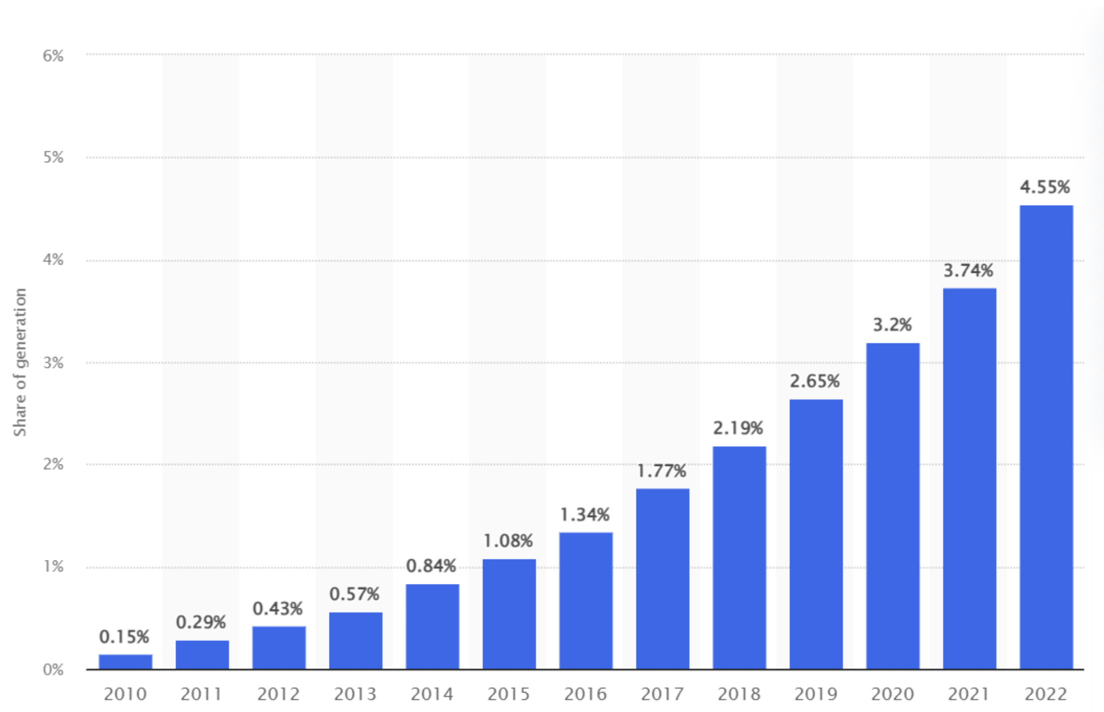


Figure 2: Share of electricity generation from solar energy worldwide from 2010 to 2022 [18]

The growth of solar PV continues to vary across regions and countries, reflecting differences in resource availability, market maturity, policy frameworks, and socio-economic factors. China remains a dominant player in the global solar PV market, with the country set to build 240 gigawatts in 2023 [19]. Other major markets include the United States, Japan, India, and the European Union [20]. Emerging markets such as Brazil, Mexico, South Africa, and Vietnam have also demonstrated strong potential for solar PV deployment [20].

However, several challenges and barriers need to be overcome to achieve ambitious visions for solar energy. These include grid integration issues, land use conflicts, environmental impacts, social acceptance, financing constraints, policy uncertainty, and regulatory hurdles [21]. Moreover, ensuring a fair and inclusive distribution of the benefits and costs of solar PV deployment will be crucial for enhancing its social and economic sustainability [20]. Therefore, a holistic and coordinated approach involving multiple stakeholders and addressing multiple dimensions is needed to foster the development of a resilient and thriving global solar PV industry [20].

B. Status Quo Assessment of Solar PV In Lebanon

1. History and Evolution of PV Installation in Lebanon

Modern PV history in Lebanon can be traced back to 2010 when the installed distributed PV systems were at around 0.3 MWp. As declared by LCEC, and presented in figure 3, this capacity started growing to reach a capacity of 90 MW in 2020 [1]. Most of this growth can be attributed to the NEEREA project loans. NEEREA was established in partnership with BDL to offer the private sector long-term, low-interest loans for energy efficiency or distributed renewable energy (RE) applications, with LCEC a loan cap of USD 10 million per project and low interest rates for terms up to 14 years, including a grace period of between six months and four years. End users received these loans straight from Lebanon's commercial banks [1]. NEEREA started its first set of loans in 2012 and peaked in 2017 to then witness a drop until completely halted in 2020.

However, even with the lack of NEEREA’s support, Lebanon’s economic and energy situation has led to an unprecedented increase in solar installations after 2020. According to LCEC, the growth of decentralized PV witnessed an even higher exponential growth from 2020 to 2023. The country saw an eightfold increase in solar energy installations from 2020 to 2022, with additional installations of about 100 MW and 500 MW in 2021 and 2022 respectively. It was also stated by LCEC that Lebanon's installed solar capacity surged past 1,000MW by mid-2023, nearing the capacity provided by private generators [12, 14, 22].

This increase in demand led to the growth of the market and its stakeholders, with a rapid increase in the number of solar energy companies, contractors, and individuals trying to reap the benefits and secure their share in this growing market [23].

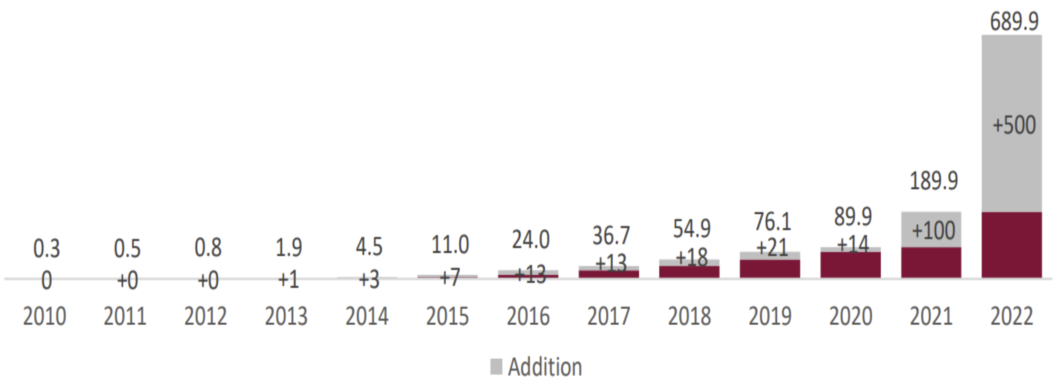


Figure 3: Decentralized Solar Installed Capacity (in MW), Source: IFI

2. *PV Potential in Lebanon*

Solar energy is an abundant source in Lebanon. With around 300 sunny days in a year and 8 to 9 hours of sunshine during the day [24], the annual average global horizontal irradiation (GHI) and the annual direct normal irradiation (DNI) across different regions are as high as 1,520 - 2,148 kWh/m2 and 2,100 kWh/m2 respectively (Figures 4 and 5) [25].

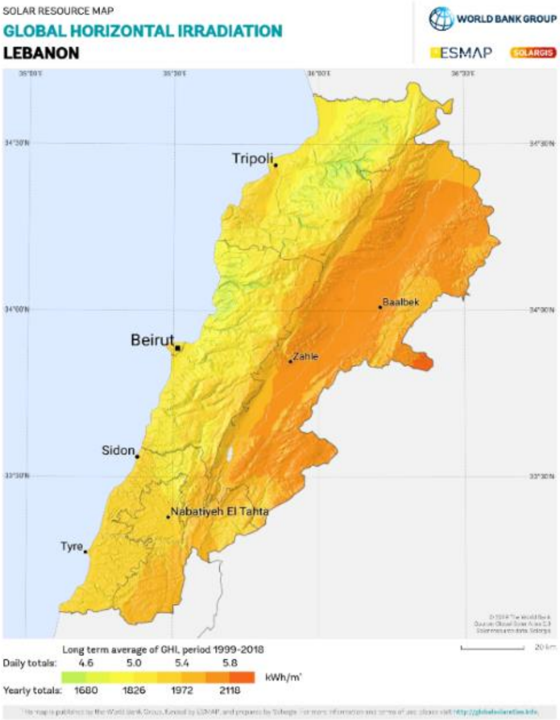


Figure 4: Global Horizontal Index (GHI) Map of Lebanon

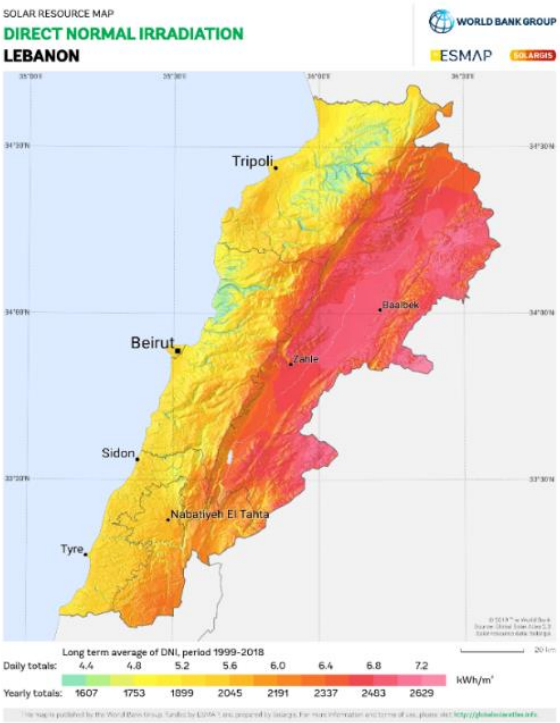


Figure 5: Direct Normal Irradiation (DNI) Map of Lebanon

Building on this solar irradiation data, International Renewable Energy Agency (IRENA) estimates that the potential for utility-scale solar PV could reach 182 GW [1]. However, the distributed solar potential is hard to estimate, given the complex procedures for evaluating the capacity for rooftop installations and the absence of local registries [1].

Other factors that support the solar PV potential in Lebanon are the fact that solar PV is modular and scalable. This is particularly important for the Lebanese people as it allows for a wide range of households and businesses to adopt solar PV systems according to their specific needs and financial capabilities. Moreover, PV-storage systems can provide an off-grid solution in light of the ongoing power outages and fuel unavailability.

3. *Overview of Existing Regulations in Lebanon*

Lebanon has issued several laws and policies over the past years to enable the deployment of renewable energy and regulate its development and existence (Figure 5) [7]. The efforts put have set an environment for solar installations but were still not sufficient to have a fully compliant sector.

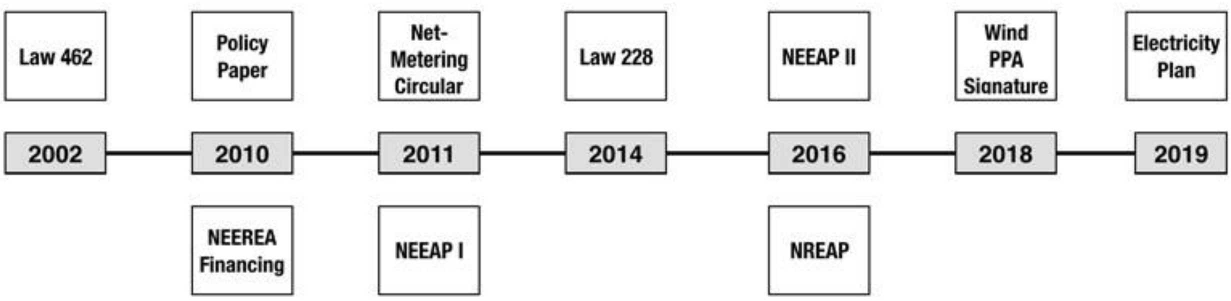


Figure 6: Major RE Laws and Policies in Lebanon

a. Laws 228/2000 - 462/2002 – 288/2014

Issued by the council of ministers in 2002, Law 462/2002 provides a backbone for the legal framework for privatization, liberalization, and unbundling of the electricity sector in Lebanon, as well as the establishment of an Electricity Regulatory Authority (ERA). This law was built on law 228/2000, which provided a structure for privatization. Law 462 stipulates that independent power producers (IPPs) can generate electricity through licenses from the ERA, and it splits the power sector into production, transmission, and distribution segments [7, 26]. Private sector participation occurs through its selling electricity to the government, which in turn sells it to the end user. In other words, generation is privatized, and distribution can also be privatized, yet transmission remains in the hands of Électricité du Liban (EDL) [27].

However, the law was never fully implemented, no ERA was formed, and "we still need stronger implementation mechanism to attract investors" as Mrs. Allaya, technical manager of distribution at EDL, states [15]. The proper implementation of this law with a review of needed amendments and the formation of the ERA would (1) unbundle the power sector and encourage a decentralized power generation, (2) involve the private sector producers, (3) regulate the market, and (4) facilitate licensing projects with a third party without the interference of the Ministry of Energy and Water (MEW) [15]. This applies to both utility-scale and distributed PV projects.

The MEW patched this up by issuing law 288/2014. With this law in action, the licensing privilege is managed by the Ministry of Finance (MoF) and the MEW who launches bids upon approval by the Council of Ministers (CoM) [28]. This law was extended by laws 54/2015 and 129/2019 until April 2022 [29]. After that, the parliament did not extend it and no legal foundation currently exists for the government to involve private sector participation through independent power producers. The ERA needs to be set up so that it acts as the entity that provides permits and licenses via an institutional framework [27]. Also, given the lack of a regulatory body, the MEW has assigned the Lebanese Center for Energy Conservation (LCEC) as its technical arm for the regulation of renewable energy (RE) projects.

b. Circular 32-318/2011 for Net Metering

Net-metering is a mechanism that allows owners of renewable energy (RE) systems to export their excess energy to the national grid in return for an equivalent deduction in their bill or another benefit. This mechanism was adopted by Electricité Du Liban (EDL) in 2011, following a circular issued by EDL, certified by the Ministry of Energy and Water (MEW), and approved by the Ministry of Finance (MoF).

The mechanism operates under EDL's Distribution Directorate and necessitated the establishment of a Net Metering Committee to oversee its implementation. A resident can currently fill out a form on the website to request an installation of a bi-directional meter (Appendix I) [30], which tracks both the energy consumed from the grid and the energy produced by the RE system.

The process necessitates that the equipment used in these RE systems, such as inverters and photovoltaic (PV) modules, should comply with certain international standards to ensure safety, efficiency, and reliability. For instance, inverters should meet safety standards like IEC 62109-1 and IEC 62109-2, while PV modules should adhere to design qualification and type approval standards like IEC 61215-1&2 or IEC 61646 [30].

However, due to a shortage of meters and trained personnel to install the equipment, no installation will take place following the application, rendering this project unsuccessful. Despite this setback, it demonstrates Lebanon’s readiness to transition to RE-based systems [29].

c. Distributed Renewable Energy (DRE) Law/ Ratified December 14, 2023

On December 14, the Lebanese parliament enacted the Decentralized Renewable Energy Law (DRE), a transformative step for the residential solar PV sector. The DRE law governs private-to-private sale of power and net-metering arrangements, making it more relevant for distributed solar PV than previous laws 228, 462, and 288. This legal advancement aligns with Lebanon's renewable energy targets as per its Nationally Determined Contributions (NDC) and the Ministry of Energy and Water's (MEW) 2019 energy policy, specifically addressing the needs of residential energy consumers [31, 32].

The law permits peer-to-peer renewable energy trading, allowing homeowners with solar PV installations to sell excess power directly to others, a process that encourages the decentralization of energy production and promotes the use of renewable resources within communities. This aspect of the law is particularly beneficial in urban and suburban settings where residents can exchange surplus energy, fostering local energy markets and making efficient use of generated power [31, 32].

Furthermore, the DRE law formalizes net metering, a critical mechanism for residential solar PV systems. It enables homeowners to receive credits for the surplus electricity they feed back into the grid, thus reducing their utility bills and encouraging the uptake of solar energy. The introduction of various net metering options—

individual, multiple-tenants, and collective—under the DRE law provides a flexible and inclusive framework, accommodating a wide range of residential arrangements and boosting the adoption of solar PV systems [31, 32].

The Lebanese Center for Energy Conservation (LCEC) projects an increase in renewable energy capacity, with 800 to 1,200 MW expected to be added in the near future, significantly bolstered by residential solar PV installations. While the law marks a substantial leap forward, it also arrives amidst challenges such as grid reliability and the establishment of a regulatory authority, issues that are crucial for the successful implementation of the DRE law [31, 32].

d. MEW's policy statement – March 2022

In the policy statement titled "Setting Lebanon's Electricity Sector on a Sustainable Growth Path," the MEW underscores the urgency of overhauling regulatory and legislative frameworks to rejuvenate its electricity sector, with a keen focus on fostering distributed renewable energy, particularly solar energy. A primary action point is the immediate establishment of the Electricity Regulatory Authority (ERA) as mandated by Law 462. This independent body is critical for monitoring, regulating, and promoting fair competition, which is essential for attracting investment in renewables [9].

Simultaneously, the statement highlights the need to revitalize or introduce legislation that specifically addresses the bottlenecks in adopting solar energy and other renewables. This includes amending or creating laws that facilitate net metering, grid integration, and feed-in tariffs, which are indispensable for a robust solar energy market [9].

The urgency to amend these frameworks stems from the acute need to mitigate the country's energy crisis, reduce its carbon footprint, and align with global energy transition trends. By setting a clear timeline and prioritizing the establishment of ERA and reforming pertinent laws, the policy statement marks a decisive step towards securing a stable, sustainable, and efficient energy future for Lebanon [9].

e. Legal Procedure to Install Solar PV

In October 2021, and upon the request of the Ministry of Interior and Municipalities (MOIM), the MEW has stipulated a mechanism to organize the licensing of distributed PV solar energy. The mechanism is illustrated in Figure 6 and outlines the regulating and governing bodies: The LCEC, the MEW, and the MOIM. The applicant should fill a form with the solar contractor and submit it in person to the MEW and electronically to the LCEC. The MEW then approves the request and forwards it to the MOIM for notice, and to the LCEC which sends the approval back to the applicant [33].

The application to the MEW should have a list of technical requirements, that are: (1) a detailed proposal study by the solar contractor that enforces safety precaution, (2) a cross sectional diagram of the mounting structure showing it doesn't exceed 3m of height on buildings shorter than 15m, and 4.5m of height on taller buildings, and (3) a structural analysis study of the mounting structure in compliance with wind load standards set by Libnor—The Lebanese Standards Institution—that is signed by a civil engineer registered in the bar [34].

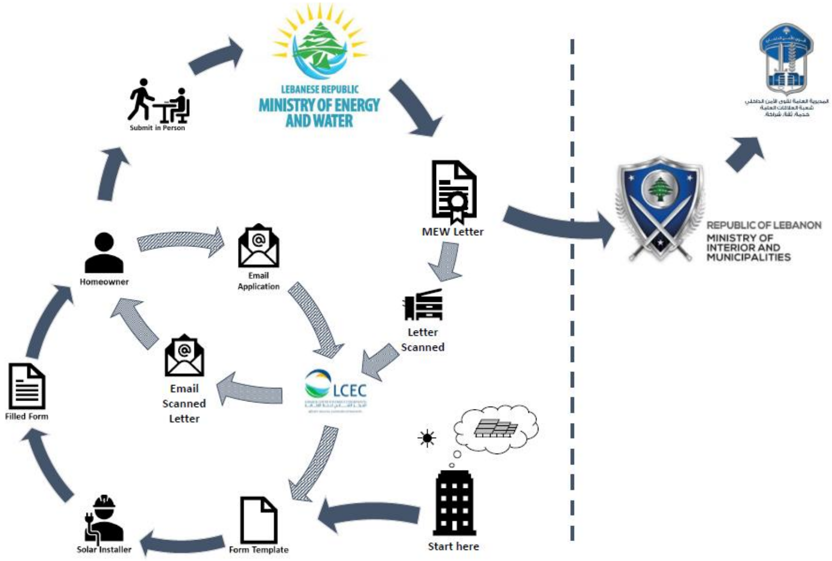


Figure 7: Legal Procedure to Install Solar PV

While the outlined procedure provides a structural framework for regulating solar installations, it encounters significant regulatory challenges. Firstly, the terminology used, such as "safety precautions," is often too vague, lacking clear, enforceable standards. This ambiguity leaves room for varied interpretations, potentially undermining the regulation's effectiveness. Secondly, the process does not clearly define qualifications for an acceptable solar contractor or criteria for "good-quality materials," making it difficult for regulators to ensure compliance and quality. Moreover, the procedure is heavily reliant on manual submissions and individual assessments, posing logistical and consistency challenges for the MEW and LCEC. Finally, there is a lack of explicit accountability measures for contractors and consumer protection provisions, raising concerns about the overall enforcement and trust in the system. Addressing these regulatory challenges is crucial for the efficient and effective implementation of solar PV installations.

C. Challenges for Developing the Solar PV in Lebanon

The development of the solar PV sector in Lebanon faces challenges that span across the journey of the three main pillars: the user, the contractor, and the regulator. Each entity encounters unique obstacles that collectively influence the sector's growth and sustainability.

1. Challenges across User Journey

a. <u>Lack of Awareness</u>

As a user decides to own a solar system, the user must choose the right system size and requirements and decide on the investment they need to make. Without proper knowledge, and within a collapsing economy, the users often find themselves choosing the cheap alternative, prioritizing savings over quality, safety, and sustainability, and being inconsiderate of the long-term yield amidst an urgent need for electricity during power shortages. In an interview with "Grand LB", solar engineer Saed Youness explains that many of those who want to install a solar energy system do not seek help from competent professionals who correctly study the project, taking all safety measures into consideration and using the appropriate accessories and components needed to face any problems.

He also states how people often are not aware or being informed by their non-specialist contractor of the instructions on handling and caring for their solar system. Those include regularly cleaning the panels and inspecting them for fractures to avoid fires, as well as making sure their inverters are constantly ventilated and having their filters cleaned weekly or biweekly [35].

As for the use of the solar energy collected, many users often lack the understanding of the technical aspects of operation and maintenance, and are not aware about concepts like power draw and energy consumption, and do not know how to read their inverters, charging, battery usage and even the solar production. They might be also unaware of the importance of energy efficiency needed in association with installing a solar system, such as having to switch the lights off, installing more efficient appliances, and so on. This reveals the user's lack of knowledge in scheduling and managing their energy consumption, often finding themselves out of power by 10 pm, not knowing what or who to blame.

This kind of challenge requires an intervention from both the private and public sector to raise awareness on the aforementioned topics, and to create a base of consumers who are more knowledgeable, energy efficient, and conscious of their decisions. This includes making users' needs accessible, presenting clear information to make informed decisions about investing in solar PV systems, as well as maintaining them and using them effectively. Ensuring that solar PV systems are user-friendly and accompanied by comprehensive service and support is vital for their successful adoption and long-term functionality, and users need such reliable support and guidance.

b. Limited Financing and Capital

Emerging out of a financial crisis, the Lebanese citizen found that the only way to get out of the electricity crisis was investing the money they have left in expensive solar energy systems, that are imported and paid for in hard currencies that became very scarce and not available to the common Lebanese citizen. Indeed, as the financial crisis started in 2019, and hit banks and financial institutions, loans were no longer a viable option. NEEREA loans were shut down, and bank loans became nearly impossible to obtain. Most people bought their solar systems from personal funds, either those they had saved or those they managed to pull out of the banks before the unofficial capital control was implemented.

Later, and in June 2022, Banque de l'Habitat (BDH) initiated a solar energy loans initiative as part of Lebanon's push towards renewable energy amidst a challenging economic landscape. Offering loans between 75 million and 200 million Lebanese pounds with a 4.99% interest rate and a repayment period of five years, the program was specifically tailored to aid low to middle-income individuals in adopting solar energy solutions [36].

The program was significantly bolstered by international partnerships and funding sources. Notably, it includes a strategic collaboration with the Arab Fund for Economic and Social Development, providing a substantial loan of approximately 165 million dollars. This funding is vital in sustaining and expanding the initiative, allowing a broader segment of the population to access solar energy loans [37].

Despite the streamlined online application process and the extensive interest reflected in the 782,000 visitors to the bank's website as of March 2023, the program faced logistic and bureaucratic challenges. According to general manager Antoine Habib, chairman of the board of directors of BDH, the primary bottleneck has been the public sector strikes and inefficiencies in the bureaucratic system, leading to a significant hurdle in obtaining necessary official documentation.

By April 2023, while 3,000 applications for solar energy loans were approved, the actual disbursement of these loans was stalled due to the inability of applicants to procure and submit the required documents, primarily due to the public sector's ongoing strikes and slowdowns [38].

Another important aspect on financing, which is specific to Lebanon, is the high cost of having to install off-grid solutions due to constant grid power outages. In most parts of the world, distributed PV is used as a tool by households to cut down the energy bill, to support the grid's energy production, to relax demand on the grid, and flatten the peak prices, with a net-metering scheme that requires a constant grid supply. In Lebanon, on the other hand, where the grid is dysfunctional and gets less and less reliable by the day, solar PV is a tool to gain energy autonomy and independence from the grid, and to have an off-grid solution. This has led most households to install battery systems with their PV systems, to store the excess electricity that otherwise would be lost because there is no reliable grid to exchange with via net metering. This poses a challenge in the growth of the solar PV sector, as storage is quite expensive, and batteries can be a major yet indispensable cost element of a system in Lebanon to ensure continuous energy supply. Solar systems in Lebanon require more capital, and the international market trend shows that the drop in the technology price of storage is not as fast as the other elements of the system (Figure 8) [23]. Therefore, a proper grid with net-metering support policies is crucial to make solar energy more affordable and accessible.

Therefore, to enhance the financing of solar energy in Lebanon, focused efforts should be directed towards: (1) diversifying and increasing solar financing tools and schemes to provide a variety of options tailored to different segments of the population; (2) ensuring the sustainability and expansion of solar energy loan programs like those initiated by Banque de l'Habitat, alongside securing continued support through international funding; (3) streamlining the loan application process by reducing bureaucratic hurdles, adopting more flexible paperwork requirements, moving towards digitalization to expedite the process; (4) activating and enabling net-metering schemes to allow for more cost-effective on-grid solar energy solutions, and (5) reducing the overall burden of investment in off-grid systems and making solar energy more accessible and affordable. These strategic directions are vital for overcoming the existing barriers and fostering a robust solar energy sector in Lebanon.

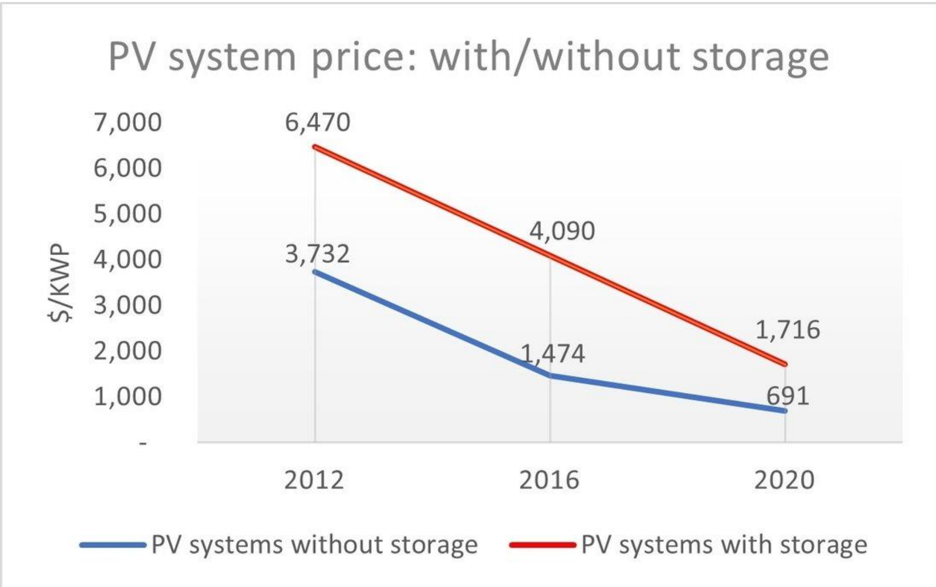


Figure 8: PV System Price - With and Without Storage; Source: LCEC

2. *Challenges Across Contractor's Journey*

a. <u>Lack of Training and Craftsmanship</u>

In recent years, Lebanon has seen a surge in solar panel installations. From the rooftops of Beirut to the farthest corners of the country, solar panels have become a common sight. This boom in demand for solar photovoltaic (PV) systems has opened up a vast market for contractors. However, this rapid growth has brought with it a significant challenge: the lack of training and craftsmanship in the solar energy market.

With the absence of stringent regulations, anyone, qualified or not, can potentially become a solar contractor. As a result, individuals from various professions have turned to solar contracting, often without the necessary expertise or experience. This lack of training can lead to catastrophic outcomes, with systems being improperly installed in terms of sizing, design, and material quality and specifications.

While the solar energy market in Lebanon is still in its early stages, and satisfaction data is not yet readily available, word-of-mouth reports of dissatisfaction are becoming increasingly common. Complaints range from improperly sized storage systems to frequent power disconnections.

Experts have raised major concerns about the durability of these installations, particularly in the face of Lebanon's harsh winter winds [39]. There are fears that many panels could be blown away, leading to significant financial losses and potential safety hazards. In fact, an incident was reported in Tripoli in July 2022, where a system caught fire due to problems in the connections, a dysfunctional inverter, and an exploded battery [40].

In an interview with Solarabic, renewable energy expert Nicolas Madani highlighted that the key issue and the root cause of most problems, from his perspective, lies in poor system design. Installers often fit cables and circuit breakers that are smaller than necessary for the system. This is due to the installer not conducting a thorough study of the system. For instance, direct current cables with a diameter of 6 or 10 mm^2 are installed for the batteries, when cables with a diameter of 25 mm^2 should be used.

This lack of proper design and installation can lead to system failures and safety issues [41].

To ensure the sustainable growth of the solar energy market in Lebanon, it is crucial to address this challenge. Implementing rigorous training programs and crafting robust regulations could be key steps towards ensuring high-quality installations and harnessing the full potential of solar energy in Lebanon.

b. Burdens in Procurement and Supply Chain Management

Contractors in Lebanon have been overwhelmed with an influx of lower-quality, cheaper solar panels, inverters, and batteries. These alternatives, competing 10-30% below the price of grade A products, are tempting in the short term but often lead to increased long-term costs due to inefficiencies and frequent failures [42].

The economic scenario complicates matters further. Since the devaluation of the Lebanese pound in 2019, the cost of materials has been highly volatile, making it difficult for contractors to maintain consistent pricing. Shipping costs to Beirut, being one of the highest in the region as noted by industry professionals, add a substantial burden, impacting the overall feasibility of renewable energy projects [23].

The COVID-19 pandemic has also been a significant disruptor, affecting the availability of materials and delaying shipments. Contractors face not only some of the highest shipping costs in the region but also delays in the arrival of equipment to Lebanon. Once equipment arrives, the absence of a clear framework for customs duties and taxes adds another layer of unpredictability. This ambiguity forces contractors to factor in contingencies for these costs, at the risk of losing market share in an increasingly competitive environment [23].

To navigate the multifaceted challenges of supply chain management in Lebanon's transition to solar power, contractors should adopt various strategic measures. These include diversifying supply sources to reduce risks associated with dependency on a single supplier, enhancing forecasting and inventory management to better anticipate and react to market fluctuations, and negotiating more flexible payment and delivery terms to stabilize costs. Additionally, there is emphasis on investing in quality assurance processes, ensuring that the materials and components procured meet high standards of quality and safety.

3. *Challenges Across the Regulator's Journey*

a. Lack of clarity of governance structure

The lack of clarity in governance structure in Lebanon's solar energy sector is a significant challenge, highlighted by the unimplemented Law 462/2002 and the absence of an Electricity Regulatory Authority (ERA). Without the ERA, no single entity currently organizes the entire solar energy ecosystem, leaving matters in the hands of the Lebanese Center for Energy Conservation (LCEC) to handle technical duties in the absence of a regulatory body. This results in fragmented responsibilities and inefficiencies, posing a significant challenge in creating a coherent, regulated market that attracts investors and systematically manages the expanding solar infrastructure [23].

The MEW's March 2022 emergency policy statement's emphasis on establishing the ERA indicates a positive move towards improved governance, promising a more coherent, regulated market that could systematically manage the expanding solar infrastructure and attract necessary investments [9].

b. Limited Regulation and Enforcement of Installation and Safety Measures

While the potential of solar energy as a solution to the country's chronic electricity shortages is promising, the lack of stringent regulatory frameworks and enforcement mechanisms for installation standards and safety measures poses significant risks [23].

Firstly, the rapid proliferation of solar energy systems has outpaced the development of comprehensive regulations and safety protocols. This has led to a market flooded with low-quality installations, carried out by individuals and entities often lacking the necessary expertise or credentials [42]. The absence of enforced standards results in installations that are not only inefficient but potentially hazardous, leading to risks such as fires and electrical accidents.

Moreover, the enforcement of the existing—albeit little—regulations is weak due to fragmented governance and lack of resources. The political and economic instability in the country further exacerbates this issue, leaving a regulatory vacuum where safety and quality often take a backseat to immediate cost savings and rapid deployment [2].

The current situation necessitates a multipronged approach. Strengthening the regulatory framework is crucial. This involves developing comprehensive, enforceable standards for the installation and maintenance of solar energy systems, coupled with a robust certification process for installers and technicians. Moreover, increasing public awareness about the importance of quality installations and the long-term danger of substandard work is essential.

On an enforcement level, it is vital to empower and resource relevant authorities to conduct regular inspections, enforce regulations, and penalize non-compliance effectively. Collaboration with international bodies and learning from global best practices can also help in developing and implementing these regulations.

D. Benchmarking of Global Best Practices to Regulate the Solar PV Industry

1. Benchmarks for Challenges across User's Journey

a. Lack of Awareness – USA's Single-Family Solar Homes Program (SASH)

Overcoming the challenge of a citizen's lack of awareness about residential solar energy requires not just informational dissemination but also practical engagement and tailored approaches. Managed by GRID Alternatives, the Single-Family Solar Homes (SASH) Program provides a compelling case study on increasing solar energy adoption in disadvantaged communities through targeted awareness.

The SASH Program was designed to bridge the gap in solar energy knowledge and accessibility for homeowners in disadvantaged communities across the United States. Funded by the California Public Utilities Commission, the program was part of a statewide initiative, originating from CA Assembly Bill 2723, which mandated that a minimum of 10% of California Solar Initiative (CSI) funds be allocated for assisting low-income households [43].

The SASH Program's comprehensive and community-centric strategy [44] included:

- In-depth Community Surveys: Understanding the specific needs and barriers faced by target communities was crucial. Surveys helped tailor the program's approach.
- Educational Materials and Workshops: A range of materials and workshops were developed, focusing on solar energy's practical aspects, benefits, and maintenance.
- Door-to-Door Campaigns: Personalized engagement with residents through door-to-door campaigns helped address misconceptions and highlight the program's benefits.
- Financial Literacy Sessions: Sessions focused on the financial aspects of solar installation, including the benefits of the program's rebates.
- Partnership with Local Entities: Collaborations with schools and community centers broadened the program's reach and impact.
- Installation Demonstrations: Live demonstrations demystified the solar panel installation process.

The program has seen significant increase in installations. Over 9,500 homes across California benefitted from the program, with over 5,200 installations under the original SASH fund and an additional 4,300 homes under SASH 2.0 as of early 2022 [43]. The program also led to enhanced awareness and empowerment, as residents gained a better understanding of solar energy, contributing to increased energy independence [43].

The SASH Program demonstrates how targeted strategies can effectively increase solar energy adoption in disadvantaged communities. Personalized engagement, educational initiatives, financial assistance, and practical demonstrations were key to the program's success. The program illustrates the importance of enhanced community awareness and engagement.

b. Limited Financing and Capital

i. Germany

Germany has become a global leader in residential photovoltaic (PV) installations through a comprehensive suite of financial incentives and regulatory support. The financing challenge for residential PV solutions encompasses aspects such as initial investment costs, ongoing maintenance, and operation costs. To address these, Germany has implemented a variety of subsidies, tax benefits, and feed-in tariffs designed to reduce the financial burden on homeowners and promote widespread adoption of solar energy. Germany is tackling the financing challenge for residential PV solutions through the following steps:

Substantial Financial Incentives for Homeowners: Germany's government has introduced a significant subsidy program aimed at encouraging homeowners to invest in solar panels, home batteries, and electric vehicle (EV) charging stations. Homeowners installing solar panels can benefit from a subsidy of €600 per kilowatt peak (kWp) of installed capacity. For home batteries, the subsidy is €300 per kilowatt-hour (kWh) of capacity, and for EV charging stations, it's €2,500 per charging point [45]. These subsidies substantially reduce the initial investment burden and make solar installations more attractive and financially viable for a broad range of households.

The Renewable Energy Sources Act (EEG) and Feed-in Tariffs: The Renewable Energy Sources Act (EEG) is a cornerstone of Germany's solar energy support, started in 2000, guaranteeing a fixed feed-in tariff for solar electricity. This means that solar power producers are paid a certain amount for each kilowatt-hour of electricity they generate, providing a predictable income stream for homeowners who invest in solar PV systems. The feed-in tariff has been a significant driver in the adoption of solar technology across the country The introduction of FITs in Germany in 2000 increased the cumulative solar PV capacity by 35% by 2012 [46]. This effect continued, as in 2021, small-scale (0-30kwp) solar PV systems' share in total capacity remained at a high of 36.2% in 2021, mainly attributed to the EEG incentives and the continuous updates to its schemes [47].

Zero VAT Rate and Tax Benefits: To further alleviate the cost burden on homeowners, the German government proposed a new zero VAT rate for the supply and installation of solar modules. This tax relief applies to both single-family residential and commercial photovoltaic (PV) and battery systems up to 30 kWp. For multifamily and mixed-use buildings, the exemption applies to solar systems up to 15 kWp per residential or commercial unit, but is limited to up to 100 kW per taxpayer. This initiative makes solar energy more affordable and accessible, and it is expected to have boosted the installation of solar systems in Germany by 20% in 2023 [46].

Income Tax Exemption for Small Solar Installations: Starting in 2023, operators of photovoltaic systems with an output of up to 30 kW on single-family homes or commercial properties will no longer have to pay income tax on the electricity yield. This tax exemption also extends to multi-family houses and mixed-use properties with a PV system of up to 15 kW. Moreover, the value-added tax (VAT) will no longer be due on the purchase, import, and installation of photovoltaic systems and energy storage systems, provided they are installed on or near private homes, apartments, and buildings used for activities serving the common good [48].

ii. California, US

California's solar leasing model represents a significant benchmark in addressing the challenge of financing residential photovoltaic (PV) solutions. This model transformed solar PV systems from a large upfront investment into an accessible service for homeowners. Key aspects of this model include:

Transformation of Solar Investment: The solar leasing model in California has made it possible for homeowners to adopt solar energy without the burden of large initial investments. Homeowners in California, instead of purchasing solar panels, are increasingly opting to lease them. This shift has been significant, with over 75% of new residential solar systems in 2012 being leased, compared to less than 10% in 2007. In 2021, the share of solar leasing in the solar market was 23%, competed mainly by the recent and attractive solar loans. The lease model effectively turned a complex investment into a manageable, cost-saving service [49].

Financial Accessibility: Leasing companies offer solar PV systems with little to no upfront costs, significantly lowering the barrier to entry for homeowners. This approach is particularly appealing in a state like California, where residential solar systems represent a substantial financial investment. The leasing model allows homeowners to enjoy the benefits of solar energy with reduced financial stress and complexity [49].

Market Growth and Leasing Advantages: The growth of solar leasing in California can be attributed to its ability to address several barriers homeowners face with solar adoption. Leasing firms handle the complexities of financing, permitting, and installation, offering a streamlined process to the consumer. This ease of access has been a key driver in the rapid adoption of solar energy in residential sectors [49].

Impact on Policy and Deployment: California's experience with solar leasing holds valuable lessons for policymakers aiming to increase solar adoption. The leasing model has demonstrated that reducing upfront costs and simplifying the solar adoption process can significantly accelerate PV deployment. Additionally, the model shows how leasing can be integrated into broader renewable energy policies to maximize impact [49].

2. *Benchmarks for Challenges across Contractor's Journey*

a. Lack of Training and Craftsmanship – USA's Licensing and Certification Systems

Licensing and certification for solar photovoltaic (PV) systems in the US are established by state and local jurisdictions to ensure that solar installers possess the qualifications, competence, and expertise to provide solar installation services. The National Electrical Code (NEC) defines a "qualified person" as someone who has the skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training [50]. However, the interpretation of "qualified person" varies by state and local jurisdiction according to state licensing and/or certification laws and standards.

Licensing is typically a mandatory requirement administered at the state level, and in some states at the municipal level. Certification is typically a voluntary credential that is administered by a third-party, non-governmental organizations [51]. Some key areas where licensing requirements may differ include: (1) whether the licensing function is administered at the state or local level, (2) the type or level of license needed to perform PV installations, (3) the components of a PV installation which are defined as electrical work and therefore require a licensed electrician to perform or supervise, and (4) the number of licensed electrical workers required to oversee non-licensed workers who also perform electrical work.

Many states require a general electrician license as a minimum credential to perform or oversee electrical work on PV installations. Other states, however, allow individuals to obtain a limited license to perform electrical work but with specified limitations, such as limiting the size of the system or narrowing the components that can be installed with a limited license. In addition to licensure, some state or municipal agencies tasked with implementing solar incentive programs require solar contractors to hold a third-party certification in order for the system to be eligible for the incentive. Utilities that offer solar incentives may also require that licensed professionals perform the PV installation in order for the customer to qualify for the incentive, including licensed general contractors and/or licensed electrical contractors [51].

In Massachusetts, there is a requirement that any person, firm, or corporation in the business of installing wires, conduits, apparatus, devices, fixtures, or other appliances for carrying or using electricity must have the appropriate electrical license [51]. This means that nearly all aspects of a solar installation must either be completed by a licensed electrician or by a person under the supervision of a licensed electrician. Although non-electrician licensed contractors can advertise or bid on solar PV projects and perform a number of the tasks associated with those projects, they still must subcontract with a licensed firm or electrician to perform the electrical aspects of the actual PV installation.

i. General Licensing

The general licensing system for solar photovoltaic (PV) installations in the US specifically focuses on the requirement for licensed electricians to perform and/or oversee PV installations in states and localities where electrical work is a licensed trade and limited electric licensing options do not exist. In such states, PV installations must be completed and/or overseen by a licensed electrician, often referred to as a "journeyman license." To operate as an electrical contractor, a company must hire a licensed "master electrician." The education and on-the-job training requirements are generally not specific to any particular area of electrical specialty, such as PV, and vary by state [51].

The regulations also state the important factor of the allowed ratio of a licensed electrician to non-licensed apprentices. The practical impact of the ratio requirement can be significantly compounded depending on whether all aspects of a PV installation are considered "electrical" and therefore must be performed or supervised by a licensed electrician (e.g., Massachusetts) or if some aspects are non-electrical and do not require the licensed electrician (e.g., Wisconsin) [51]. A very low (e.g., 1:1) ratio requirement for PV installations means that a higher number of licensed electricians may be required per installation (Table 1).

State	License type	Minimum training required	Ratio of licensed electrician to non-licensed apprentice
Idaho	Journeyman	Classroom: 576 credit hours (4 years). On-the-job training: 8,000 hours (4 years)	1:3
Massachusetts	Journeyman	Classroom: 600 credit hours. On-the-job-training: 8,000 hours (4 years)	1:1
Minnesota	Journeyman	On-the-job training: 8,000 hours (4 years)	1:2
Wisconsin	Journeyman	Classroom: no minimum requirement (but educational experience may be claimed toward required experience. On-the-job experience: 8,000 hours (4 years)	1:1

Table 1:General Electrician Licensing in Selected States: Training and Ratio Requirements

Also, tradeoffs should be considered when setting ratio requirements and defining which aspects of a PV installation are "electrical" work. For instance, if all aspects of a PV installation are defined as "electrical," a licensed electrician and supervisee must perform all aspects of the installation. This ensures that trained electricians perform the entire installation; however, this also increases the labor cost compared to an installation where a licensed electrician performs only some aspect of the installation [51].

ii. Limited Licensing

The limited electric license is a license obtained by a person or firm that allows that person to perform a discrete and often narrow scope of work in a specified electric field, such as solar PV. The limited license is distinct from a specialty license, which is obtained in addition to a general electrician's license to either comply with additional licensing requirements or highlight a particular area of expertise, such as PV [51].

Some states provide limited electric licensing for particular sub-fields of electric work. The limited license requires focused training in the field, requiring less time to complete than a general electrician's license. It enables the license holder to perform a defined scope of electrical work limited to the particular subfield. One potential benefit of creating a limited license class for PV is a lower labor cost associated with a limited license holder as compared to the general license holder due to the narrowed scope of electrical training [51].

The state of Oregon offers many different electric license classifications, including limited electric licenses. For example, Oregon's Limited Renewable Energy Technician (LRT) license permits the holder, as the employee of a licensed electrical contractor, or limited renewable energy contractor, to install, maintain, replace or repair electrical wiring and electrical products on renewable electrical energy systems up to 25 kW. For PV systems, this allows the Limited Renewable Energy Technician to complete nearly the entire installation, including installing the inverter. A fully licensed electrician, however, must perform the grid interconnection. Table 2 shows examples of the license type and respective minimum training requirement for some states [51].

State	Name/License Type	Minimum Training Required
California	C-46 Solar Contractor	Classroom: no minimum; On-the-job-training: 4 years of solar experience (apprenticeship training and advanced education is credited, but 1 year of practical experience required
Connecticut	PV-1 – Limited Solar Electric Contractor	Classroom: 144 hours; On-the-job training: 4,000 apprentice hours (2 years)
Oregon	Limited Renewable Energy Technician	Classroom: 144 hours; On-the-job training: 4,000 apprentice hours (2 years)

Table 2:Examples of Solar "Limited" Electric Licenses and Training Requirements

iii. Third-Party Certification

Third-party certification for solar Photovoltaic (PV) systems in the US is based on credentialing for solar industry professionals that is administered by non-government organizations such as nonprofit organizations, professional associations, or industry trade organizations. These organizations provide certification programs that ensure that solar installers possess the qualifications, competence, and expertise to provide solar installation services. One of the most well-known PV certification programs for solar industry professionals is provided by the nonprofit North American Board of Certified Energy Practitioners (NABCEP). Other organizations such as the Electrical Training Alliance and Underwriters Laboratory (UL) also offer solar-specific certifications [51].

NABCEP offers two certifications, the "Photovoltaic Associate" (formerly called "Entry Level") certification and the "PV Installation Professional" certification. The associate certification allows entry-level individuals to demonstrate basic knowledge and skills, while the PV installation professional certification is intended for experienced professionals and requires specific experience, advanced PV training, and an Occupational Safety and Health Administration (OSHA) 10-hour construction industry card or equivalent, as well as continuing education [51].

Third-party certification is used by some jurisdictions as a means to establish eligibility for participation in solar incentive programs. In states that have statewide licensing requirements, third-party certification is often voluntary or supplemental to the statewide licensing requirement, or in some cases, such as Connecticut, an additional credential necessary to access state incentives. For example, The Energy Trust of Oregon has adopted an independent certification system for program eligibility [51].

b. Burdens in Procurement and Supply Chain Management - First Solar's Transformation in Procurement and Supply Chain Management

First Solar's journey in enhancing supply chain management in the solar energy sector provides valuable insights for businesses and countries facing similar challenges. This case study examines how First Solar, a prominent solar panel manufacturer and solar power plant manager, overcame significant supply chain hurdles by strategically implementing a software solution, focusing on the broader implications rather than the specifics of the software itself.

First Solar, based in Tempe, Arizona, managed an extensive supply chain with over 3500 suppliers and a network encompassing over 33,000 individuals globally. The company initially grappled with capacity constraints and had not emphasized demand planning, leading to operational inefficiencies. As demand grew, adjusting production rates became increasingly difficult, making the supply chain inflexible. Additionally, the existing ERP system was inadequate for managing inventory levels effectively, resulting in reliance on manual, spreadsheet-based processes [52].

To address these challenges, First Solar made a pivotal decision to implement a cloud-based supply chain management solution, Kinaxis® RapidResponse®. This decision marked a transition from a capacity-focused approach to a demand-driven supply chain model. The implementation of this software solution enabled the company to gain greater control over its complex supply chain within a remarkably short timeframe of eight weeks from the signing of the purchase order. The software provided improved visibility into inventory levels and helped balance inventory to meet targets. Despite a significant reduction in workforce, First Solar maintained efficient operations, owing to the automation and streamlining capabilities of the software [52].

The adoption of the supply chain management software led to substantial improvements at First Solar. The company saw a reduction in overall inventory by 8% and a reduction in aged finished goods inventory by 84%. The sales team was able to access real-time data on product availability, leading to a 10% reduction in overall inventory within just three months. Furthermore, the Sales and operations planning (S&OP) process was enhanced, becoming more inclusive and emphasizing cross-functional visibility [52].

First Solar's strategic shift to include building utility-scale power plants and selling energy necessitated an adaptable supply chain management system, which was achieved through the software. This adaptability allowed the company to seamlessly transition from planning individual modules to managing components of a full energy solution. The case of First Solar highlights the importance of advanced software solutions in managing complex supply chains and adapting to market changes. This approach can serve as a model for countries that want to lead a more efficient, responsive supply chain management and strengthen their positions in the competitive solar energy market.

3. *Benchmarks for Challenges Across Regulator's Journey:*

a. <u>Lack of Clarity of Governance Structure – China's National Energy Administration</u>

China's remarkable journey in solar energy production is a testament to the effectiveness of clear and centralized governance. As the world's leader in solar energy capacity, China's governance model offers critical insights into successfully managing and expanding solar energy initiatives. This case study explores how China's National Energy Administration (NEA) and overarching government policies have addressed the crucial aspects of solar energy governance.

China's commitment to becoming a global leader in renewable energy has been driven by its need to address environmental concerns, reduce dependence on imported fossil fuels, and lead in global energy technology. The government recognized early on that achieving these goals required a unified and strategic approach to regulating and encouraging solar energy development, therefore founding NEA. NEA is pivotal in shaping the country's solar energy landscape. This section delves deep into the multifaceted role of the NEA, discussing its responsibilities, strategies, and impacts in detail.

Comprehensive Oversight and Policy Formulation: The NEA develops overarching strategies, including five-year plans and specific solar energy policies, setting ambitious targets for solar capacity and technological innovation [53]. It coordinates with various governmental layers to ensure effective nationwide policy implementation.

Legislative Framework and Regulatory Role: The NEA significantly influences the Renewable Energy Law, shaping mechanisms like feed-in tariffs and renewable energy certificates [54]. It ensures that these frameworks are regularly updated, reflecting market needs and technological advancements.

Setting Standards and Certification: Establishing and updating national standards for solar power equipment and installation is a key NEA role. It collaborates with industry and international bodies to maintain up-to-date, safety-compliant standards [55].

Training and Skill Development: The NEA sponsors training programs, fostering a skilled workforce capable of supporting solar industry expansion and innovation [56].

Financial Incentives and Support Mechanisms: The NEA designs financial incentives such as feed-in tariffs and subsidies, adjusting them according to market conditions to drive solar energy adoption [57].

Consumer Protection and Quality Assurance: Enforcing regulations for consumer protection and quality assurance is a critical NEA function. This includes warranty standards, service contracts, and dispute resolution mechanisms [58].

Monitoring, Enforcement, and Adaptation: The NEA monitors solar energy projects, ensuring compliance and adapting policies based on performance data and market conditions [55]

International Collaboration and Leadership: The NEA's role extends to international collaboration, sharing experiences and promoting Chinese solar technology on the global stage [57].

b. Limited Regulation and Enforcement of Installation and Safety Measures – USA

The United States presents a comprehensive and detailed approach to regulating solar photovoltaic (PV) installations, combining local, state, and federal guidelines to ensure safety, efficiency, and reliability. This model is characterized by specific standards, training requirements, and performance metrics, which together create a robust regulatory framework. These aspects are detailed below, encompassing building codes, permitting and inspection, fire and electrical codes, as well as planning and zoning regulations [51].

i. Building Codes for Solar Installations

In the US, building codes such as the International Residential Code (IRC) and the International Building Code (IBC) set foundational standards for solar PV installations. The IRC, which applies to detached one- and two-family dwellings and townhouses up to three stories, mandates that roofs be structurally capable of supporting additional loads from solar modules and racking systems, typically not exceeding 4.5 pounds per square foot (psf). It also requires that these installations be less than 18 inches above the roof to not impede any emergency services and that all roof or wall penetrations be flashed and sealed to prevent entry of water, rodents, or insects. The IBC covers other building types and requires rooftop solar systems to have the same fire classification as the roof assembly itself, ensuring consistency in fire safety measures across the structure. It also includes criteria for calculating minimum design loads for rooftop solar PV systems, providing guidance on wind load engineering calculations [51].

Oregon's Solar Installation Specialty Code, the nation's first statewide solar code, exemplifies the adaptation and specification of these general codes to local needs.

This comprehensive code includes provisions that streamline the permitting process for installations that meet a set of predefined criteria, significantly reducing the administrative burden and expediting the deployment of solar technologies [51].

ii. Permitting and Inspection

The permitting and inspection regime in the US is designed to enforce compliance with the aforementioned building codes and additional local standards. Before installation, solar PV systems typically require a building permit, ensuring that the proposed system design meets all local building, fire, and electrical codes. Post-installation, inspections by qualified local officials are necessary to confirm adherence to the permitted design and all applicable codes. These inspections cover a wide range of aspects, including structural integrity, electrical safety, and fire protection [51].

The Interstate Renewable Energy Council (IREC) promotes best practices in this domain, advocating for streamlined permitting processes, reasonable fees, and trained staff. Streamlined processes include online permit submissions and expedited reviews for standard systems, reducing both the time and cost of solar deployments [51].

iii. Fire and Electrical Codes

Fire and electrical safety is paramount in solar PV installations, addressed through various codes and standards. The National Electric Code (NEC) sets forth comprehensive safety standards for all aspects of electrical installation, including solar PV systems. It provides detailed requirements for wiring methods, materials, and equipment to ensure safe electrical operations [51].

One critical aspect of electrical safety in solar installations is the inclusion of rapid shutdown systems. These systems are designed to quickly de-energize PV panels and components, reducing the risk of electrical shocks in emergency situations, particularly during fires. The NEC specifies that these systems must be able to bring the voltage of solar panels down to safe levels within 30 seconds of activation [51].

Signage and labeling are also essential components of the NEC's safety provisions. They require clear marking of electrical equipment, including solar PV components, to warn and inform both professional installers and emergency responders about potential electrical hazards. This includes labels for disconnecting means, warning about the presence of multiple power sources, and indicating the operational state of electrical circuits [51].

iv. Planning and Zoning Regulations

Planning and zoning regulations significantly influence the physical layout and aesthetic integration of solar PV systems, particularly in urban and suburban settings. These regulations can dictate the permissible location, size, and even appearance of solar installations. Zoning laws often include provisions for height restrictions, setbacks, and lot coverage that can inadvertently impact the feasibility of solar installations. However, many localities are adopting solar-friendly zoning amendments, including exemptions or streamlined processes for solar installations, to encourage renewable energy adoption [51].

In addition to structural considerations, zoning regulations also address solar access rights and roof-space sharing, particularly relevant in densely populated areas or multi-tenant buildings. Laws like California's Solar Rights Act ensure that property owners have the right to install solar energy systems and receive adequate sunlight. For shared or communal buildings, arrangements and agreements are often required to outline the shared responsibilities and benefits of the installation, ensuring that all parties involved have their interests protected and responsibilities clearly defined [51].

In conclusion, the US model offers a robust and comprehensive approach to regulating solar PV installations. It addresses the various safety, technical, and community aspects through a detailed set of codes and regulations, ensuring that solar installations contribute positively to the community's energy needs while adhering to strict safety standards. This model, with its focus on local adaptability, rigorous safety standards, and facilitative measures for deployment, provides a valuable framework for countries looking to strengthen their solar energy infrastructure and regulatory environment.

CHAPTER IV

RESULTS AND ANALYSIS

A. Policy Directions to Regulate the Solar PV Industry in Lebanon

Based on the challenges and benchmarks identified, we can apply lessons learned from international case studies to inspire what needs to be done in Lebanon to overcome these challenges. Policy directions are identified across each challenge accordingly.

1. *Policy Direction for User's Journey:*

a. Lack of Awareness

Lebanon's struggle with the lack of awareness among solar PV system users parallels the initial challenges faced in disadvantaged communities in the USA before the implementation of the Single-Family Solar Homes (SASH) Program. In Lebanon, the gap in consumer knowledge leads to poor choices regarding system size, quality, and maintenance, impacting the overall efficacy and safety of solar PV installations. Similarly, the SASH Program addressed the knowledge disparity in low-income households in the USA, focusing on increasing solar energy adoption through awareness and engagement. The relevance lies in the shared core issue: the need for a well-informed consumer base to make the most of solar PV systems.

i. Lessons Learned from SASH

The SASH Program's success in the USA offers valuable insights for Lebanon:

Community-Centric Approach: Tailoring awareness programs to the specific needs of different communities ensures relevance and effectiveness.

Educational Outreach: Workshops, educational materials, and practical demonstrations demystify solar technology and empower users to make informed decisions.

Personalized Engagement: Door-to-door campaigns and local partnerships enhance trust and receptiveness among potential solar PV users.

Financial Literacy: Understanding the economic aspects of solar PV systems, including cost-benefit analysis, is critical for informed decision-making.

ii. Gaps Addressed by the Benchmark

Both Lebanon and the USA faced the challenge ensuing out of the lack of awareness regarding the PV systems, but the SASH Program demonstrates a successful model of bridging this gap. Lebanon can learn from the structured approach of SASH, which combined educational initiatives with community engagement. However, Lebanon’s unique socio-economic context, including its collapsing economy and the current energy crisis, creates specific gaps that can be addressed by adapting elements of the SASH model. For instance, Lebanon's approach must consider the urgency of the situation and the diverse socio-economic backgrounds of its residents.

iii. Policy Directions for Lebanon

Customized Educational Programs: Develop educational programs and materials tailored to the Lebanese context, focusing on the practical aspects of solar PV system installation, maintenance, and operation. This includes workshops, informational sessions, and online resources in local languages.

Community Engagement and Partnerships: Leverage local community networks, NGOs, and educational institutions to disseminate information. This grassroots approach can build trust and ensure the program's relevance to different communities in Lebanon.

Financial Literacy and Economic Incentives: Include sessions or materials on the economic aspects of solar PV investments, highlighting potential savings and incentives. This is crucial in Lebanon's strained economic environment.

Demonstration and Practical Engagement: Implement demonstration projects in various communities to showcase the installation and benefits of solar PV systems. This practical approach can dispel myths and build confidence in the technology.

Adaptation to Local Challenges: Ensure that the awareness programs address specific Lebanese challenges, such as navigating the current economic crisis, dealing with infrastructural constraints, and understanding the specificities of solar PV technology in a Lebanese setting.

By adopting these policy directions, Lebanon can significantly improve the awareness and understanding of solar PV systems among its populace, ensuring safer, more efficient, and sustainable solar energy utilization. This approach will not only address the immediate need for reliable energy but also pave the way for long-term sustainable energy solutions in the country.

b. Limited Financing and Capital

The challenge Lebanon faces in financing solar PV installations is mirrored in Germany's and California's experiences. Lebanon's current economic crisis exacerbates the difficulty for citizens to invest in solar energy, highlighting the need for accessible financing options. Germany's approach, with its subsidies, tax benefits, and feed-in tariffs, and California's solar leasing model both offer valuable insights into making solar energy financially feasible for a wide range of income groups.

i. Lessons Learned from Germany and California

Germany’s Financial Incentives: Germany's subsidies and feed-in tariffs have significantly reduced the financial burden on homeowners, making solar investments more attractive.

Tax Benefits: Germany’s zero VAT rate and tax benefits for small solar installations provide a direct financial advantage to homeowners, encouraging solar adoption.

California’s Solar Leasing Model: By transforming solar PV systems from a high upfront cost investment into a manageable service, California has made solar energy more accessible to a broader demographic.

ii. Gaps Addressed by the Benchmark

The Lebanese situation is similar to the pre-subsidy era in Germany and the pre-leasing era in California, with high upfront costs being a major barrier. However, Lebanon's unique challenges, such as its economic crisis and unreliable grid, necessitate adaptations of these models. Germany’s model can be tailored to offer financial relief for the initial investment, while California’s leasing model can provide an alternative to the traditional purchase model, reducing upfront costs and making solar energy more accessible.

iii. Policy Directions for Lebanon

Introduction of Subsidies and Incentives: Implement subsidy programs similar to Germany’s, reducing the initial cost of solar PV systems for homeowners to the best of the country’s ability.

Tax Benefits and Reliefs: Introduce tax benefits or VAT exemptions for solar PV installations to lower the overall investment cost, all the while bearing in mind the dysfunctional Lebanese tax collection system, rendering taxes less of a pain point for citizens to be relieved of.

Adopt a Solar Leasing Model: Explore the feasibility of a solar leasing model, akin to California's, to offer solar PV systems with minimal upfront costs.

Feed-in Tariffs and Net Metering: Develop feed-in tariffs and effective net metering policies to provide a predictable income stream or cost-saving mechanism for solar PV system owners.

Tailored Financial Solutions: Given Lebanon's unique challenges, including grid unreliability and economic instability, financial solutions should be specifically designed to address these. This could include funding for off-grid solutions or battery storage, and partnerships with international financial institutions for low-interest loans or grants.

Streamlining Loan Processes: Simplify and expedite the loan application process, including adopting digital platforms, to ease the acquisition of solar PV systems.

By incorporating these policy directions, Lebanon can significantly improve the financial accessibility of solar PV systems, making them a viable option for a larger segment of its population. This approach will address one of the major barriers to solar adoption and contribute to the growth of the solar energy sector in Lebanon.

2. *Policy Direction for Contractor's Journey*

a. Lack of Training and Craftsmanship

Lebanon's current challenge with the lack of skilled craftsmanship in the solar PV sector is notably similar to the issues faced in the early stages of solar PV development in the USA. The key to addressing this in the USA has been the implementation of rigorous licensing and certification systems at both state and local levels. These systems ensure that solar installers have the necessary qualifications and expertise, thus guaranteeing the quality and safety of solar installations.

i. Lessons Learned from the USA's Licensing and Certification Systems

Standardized Qualifications: The establishment of defined qualifications and competencies for solar installers ensures a high standard of installations.

Mandatory Licensing and Certification: Making licensing mandatory for solar installers and providing certification pathways creates a professional and skilled workforce.

Varied Licensing Requirements: Different states in the USA have different licensing requirements, showing the importance of tailoring licensing systems to local contexts.

Quality Assurance: Licensing and certification provide a level of quality assurance to consumers, increasing trust in solar PV technology.

ii. Gaps Addressed by the Benchmark

Both Lebanon and the USA recognize the critical need for skilled professionals in the solar PV sector. The US model of licensing and certification can be adapted to Lebanon's context, addressing the current lack of skilled workforce. However, Lebanon must consider its unique socio-economic challenges and the current stage of its solar PV market development when adapting these systems.

iii. Policy Directions for Lebanon

Implement a Licensing System: Establish a mandatory licensing system for solar PV installers in Lebanon. This system should define the necessary skills, knowledge, and safety training required to become a licensed installer.

Develop Certification Programs: Create certification programs, potentially in collaboration with international organizations or local technical institutes, to provide advanced training and credentials to solar PV professionals.

Tailor Requirements to Local Needs: Design the licensing and certification requirements to address Lebanon's specific needs, considering factors like the current economic situation and the prevalent types of solar installations.

Regular Updates and Continuous Learning: Ensure that the licensing and certification programs are regularly updated to keep pace with technological advancements in solar PV. Incorporate continuous learning and skill development as part of the licensing renewal process.

Public Awareness and Trust Building: Use the licensing system as a tool to build public trust in solar PV installations. Publicize the importance of using licensed professionals for solar installations to ensure safety and efficiency.

Incentivize Skilled Labor Development: Provide incentives for professionals to undergo training and obtain licenses, such as access to more lucrative contracts, eligibility for government projects, or financial subsidies for training costs.

Quality Control and Monitoring: Implement regular inspections and quality control measures to ensure that licensed professionals maintain high standards in their installations.

By adopting these policy directions, Lebanon can significantly improve the quality of solar PV installations, ensuring that they are safe, efficient, and reliable. This approach will also contribute to the creation of a skilled workforce, capable of supporting the growth of the solar energy sector in Lebanon.

b. Burdens in Procurement and Supply Chain Management

Lebanon's solar PV sector faces significant challenges in procurement and supply chain management, similar to what First Solar experienced. The Lebanese market struggles with fluctuating costs, low-quality materials, and logistical complexities, much like First Solar did before transforming its supply chain strategy. First Solar’s adoption of advanced supply chain management solutions and shifting to a demand-driven model offer valuable insights for Lebanon’s solar sector, emphasizing the importance of efficient, responsive supply chain management.

i. Lessons Learned from First Solar's Transformation

Strategic Utilization of Advanced Software: Implementing sophisticated supply chain management tools can greatly enhance visibility, efficiency, and responsiveness.

Shift to Demand-Driven Model: Transitioning from a capacity-focused to a demand-driven supply chain model can help in adapting to market fluctuations and customer needs.

Enhanced Inventory Management: Effective management of inventory levels prevents overstocking or shortages and reduces costs.

ii. Gaps Addressed by the Benchmark

The Lebanese solar sector's situation is analogous to First Solar's initial challenges, with inefficiencies and a lack of responsive supply chain management. However, Lebanon's economic constraints and market size pose unique challenges that require a tailored approach. Adapting First Solar's strategies to the Lebanese context involves considering local market dynamics, economic conditions, and the availability of technological resources.

iii. Policy Directions for Lebanon

Adopt Advanced Supply Chain Management Tools: Encourage Lebanese solar contractors to utilize modern supply chain management software that offers real-time data, inventory management, and demand forecasting.

Diversify Supply Sources: Promote diversification of suppliers to reduce reliance on single sources and mitigate risks associated with supplier dependency.

Quality Assurance and Standards: Implement stringent quality assurance processes to ensure that imported solar components meet high standards, addressing the influx of low-quality materials.

Responsive and Adaptive Approach: Develop a more responsive and adaptive supply chain strategy that can quickly adjust to market changes, currency fluctuations, and logistical challenges.

Negotiate Flexible Terms: Work with suppliers and shipping companies to negotiate more flexible payment and delivery terms, stabilizing costs in a volatile economic environment.

Leverage Local and Regional Partnerships: Explore partnerships within the region to mitigate high shipping costs and streamline the procurement process.

Governmental Support in Customs and Taxation: Advocate for clear governmental policies on customs duties and taxes for solar equipment to reduce unpredictability and enhance market stability.

Capacity Building in Supply Chain Management: Conduct workshops and training programs for solar contractors on efficient supply chain management, leveraging lessons from successful global practices.

By implementing these policy directions, Lebanon can enhance the efficiency and resilience of its solar PV sector's supply chain, overcoming current procurement challenges and paving the way for a more robust and sustainable solar energy market.

3. *Policy Direction for Regulator's Journey*

a. <u>Lack of Clarity of Governance Structure</u>

Addressing Lebanon's current challenge of a vague governance structure in the solar energy sector is critical for its future development. The absence of an Electricity Regulatory Authority (ERA) and the unimplemented Law 462/2002 has left a gap in systematic regulation and organization. China's model, under the National Energy Administration (NEA), provides a stark contrast, showcasing how a centralized and clear governance structure can significantly enhance the efficiency and growth of the solar sector.

i. Lessons Learned from China's NEA

Centralized Oversight and Policy Formulation: NEA's role in developing cohesive strategies and coordinating nationwide policy implementation underlines the importance of centralized governance.

Regular Legislative Updates: NEA's influence in shaping and updating the Renewable Energy Law reflects the need for dynamic and responsive legislation in the solar sector.

Standards and Certification: Establishing national standards and certification processes ensures consistent quality and safety in solar power equipment and installations.

Financial Incentives and Support: The design of financial incentives like feed-in tariffs and subsidies by the NEA underscores the role of governance in driving solar energy adoption.

ii. Gaps Addressed by the Benchmark

While Lebanon faces the challenge of a fragmented governance structure, China's NEA model demonstrates the efficacy of a centralized, clear governance system. Lebanon can learn from China’s experience in providing comprehensive oversight, policy formulation, and implementation. However, Lebanon must adapt these insights to its unique socio-political and economic context.

iii. Policy Directions for Lebanon

Establish a Central Regulatory Authority: Advocate for the swift establishment of the Electricity Regulatory Authority (ERA) in Lebanon to centralize governance in the solar sector.

Develop a Comprehensive Solar Policy Framework: Encourage the MEW to create a comprehensive solar energy policy framework, including clear goals, standards, and regulatory guidelines.

Responsive Legislative Framework: Ensure that the legal framework for solar energy is regularly reviewed and updated to reflect market needs and technological advancements.

Implement Standards and Certification Processes: Develop national standards and certification for solar equipment and installations to ensure safety and quality.

Strengthen Financial Incentives and Support Mechanisms: Design and implement financial incentives, including subsidies and feed-in tariffs, to encourage investment in solar energy.

Enhance Training and Skill Development Programs: Collaborate with educational institutions and international organizations to sponsor training programs and build a skilled workforce for the solar industry.

Consumer Protection and Quality Assurance: Implement regulations for consumer protection, warranty standards, service contracts, and dispute resolution mechanisms.

Monitoring and Enforcement: Establish mechanisms for monitoring compliance and enforcement, adapting policies based on performance data and market trends.

By adopting these policy directions, Lebanon can establish a more coherent and effective governance structure for its solar PV sector, creating a regulated market that attracts investment and systematically manages solar infrastructure development.

b. Limited Regulation and Enforcement of Installation and Safety Measures

Lebanon's solar PV sector suffers from limited regulation and enforcement, mirroring early stages of solar development in the US. The US has since established a comprehensive framework that ensures safety, efficiency, and reliability in solar installations. This framework, which includes building codes, permitting and inspection processes, and fire and electrical codes, offers a valuable model for Lebanon to develop a robust regulatory environment.

i. Lessons Learned from the US Model

Comprehensive Building and Electrical Codes: The adoption of specific standards like the International Residential Code (IRC) and the National Electric Code (NEC) in the US highlights the importance of having detailed regulations for solar installations.

Streamlined Permitting and Inspection Processes: Efficient permitting and rigorous inspection regimes ensure compliance with safety standards and are vital for Lebanon's growing solar sector.

Safety Protocols and Standards: Implementing safety measures like rapid shutdown systems and clear signage ensures the safety of both installers and emergency responders.

Adaptability to Local Needs: The Oregon Solar Installation Specialty Code shows how local adaptation of general codes can effectively address specific regional requirements.

ii. Gaps Addressed by the Benchmark

Lebanon's current state of fragmented and weak regulation in solar installations runs parallel to the US's early solar development stages. However, Lebanon's unique socio-political and economic context demands a tailored adaptation of the US model, focusing on feasible and enforceable regulations suitable for Lebanon’s specific challenges.

iii. Policy Directions for Lebanon

Develop Specific Solar Installation Codes: Advocate for the creation of Lebanon-specific solar installation codes, adapting international standards to local needs.

Establish Streamlined Permitting and Inspection: Implement efficient permitting processes and rigorous inspection regimes, and leveraging digital tools for speed and transparency.

Enforce Safety Standards: Mandate safety measures in solar installations, such as rapid shutdown systems, and ensure proper signage for electrical safety.

Increase Public Awareness: Educate the public and industry stakeholders about the importance of adhering to safety standards and the risks of non-compliance.

Empower Enforcement Agencies: Provide necessary resources and authority to relevant agencies for enforcing solar installation regulations and penalize non-compliance.

Facilitate Training and Certification: Encourage training and certification programs for installers to ensure compliance with the established standards.

Promote Solar-Friendly Zoning Amendments: Advocate for solar-friendly amendments in zoning laws to support the adoption of solar installations in urban and suburban settings.

Protect Solar Access Rights: Ensure laws that protect solar access rights, especially in communal living spaces, to facilitate solar adoption.

By following these policy directions, Lebanon can establish a well-regulated solar PV sector, ensuring safe, efficient, and sustainable solar installations. This approach will address critical safety concerns and pave the way for a robust growth in Lebanon's solar energy infrastructure.

CHAPTER V

RECOMMENDATIONS

A. Initiatives

In this critical section of the thesis, I delve into a series of crafted initiatives designed to address the multifaceted challenges faced by Lebanon's solar PV sector. These initiatives are the culmination of an extensive analysis of both local contexts and global best practices, tailored to the unique socio-economic, political, and environmental landscape of Lebanon. Each initiative presents a strategic, actionable plan that not only tackles specific challenges identified in the preceding chapters but also aligns seamlessly with the overarching policy directions proposed.

Drawing insights from international benchmarks and adapting them to Lebanon's needs, these initiatives encompass a broad spectrum of activities - from regulatory reforms and capacity building to technological innovations and public engagement strategies. These are not standalone solutions; rather, they function as interconnected components of a comprehensive framework aimed at revitalizing and sustaining Lebanon’s solar energy sector.

The initiatives have been designed with a keen awareness of the key stakeholders involved – including government bodies, private sector players, international partners, and the Lebanese citizenry. Their roles and responsibilities are clearly delineated, ensuring a collaborative approach towards implementation. Moreover, each initiative is accompanied by a detailed implementation map, highlighting the steps and processes necessary for successful execution.

The potential impact of these initiatives extends beyond immediate technical and regulatory improvements; they are envisioned to catalyze a transformative shift in Lebanon's energy landscape. By fostering a reliable, efficient, and safe solar energy sector, these initiatives aim to pave the way for energy independence, economic revitalization, and environmental sustainability in Lebanon.

1. ***Initiative 1: Solar Energy Awareness and Education Program (SEEP)***

a. <u>Challenge Addressed</u>

This initiative addresses the challenge of "Lack of Awareness" in Lebanon's solar energy sector, taking inspiration from the USA’s Single-Family Solar Homes (SASH) Program. SEEP is designed to enhance public understanding and engagement regarding solar PV systems, thereby fostering informed decision-making among potential users.

b. <u>Description</u>

The Solar Energy Awareness and Education Program (SEEP) will be a comprehensive campaign aimed at educating the Lebanese public about the benefits, maintenance, and technical aspects of solar PV systems. The program will include workshops, informational resources, community engagement, and media campaigns to promote knowledge and awareness about solar energy.

c. <u>Implementation Map</u>

Development of Educational Materials: Create user-friendly guides, brochures, and online content covering solar energy basics, benefits, installation processes, and maintenance.

Workshops and Training Sessions: Conduct workshops in collaboration with local community centers, schools, and universities to provide hands-on learning experiences.

Partnerships with Industry Experts: Collaborate with solar energy companies and technical experts to ensure accurate and up-to-date information.

Community Engagement Campaigns: Organize community events and activities to engage the public in learning about solar energy.

Media and Online Campaigns: Utilize television, radio, and social media platforms to reach a wider audience.

Feedback and Evaluation: Implement a system to gather feedback from participants and continuously improve the program.

d. Stakeholders and their Roles

Stakeholder	Role
Ministry of Energy and Water (MEW)	Oversight and support for SEEP, ensuring alignment with national energy policies.
Lebanese Center for Energy Conservation (LCEC)	Provision of technical knowledge and resources for educational content.
Educational Institutions	Hosting workshops and integrating solar energy topics into curricula.
Solar Energy Companies	Collaboration in community events and providing expert insights.
Media Outlets	Dissemination of informational campaigns to reach a broad audience.
Local Community Centers	Hosting community engagement events and workshops.
Consumers	Participation in workshops and spreading awareness in communities.

Table 3: Initiative 1 stakeholders

e. <u>Potential Impact</u>

Impact	Description
Increased Public Knowledge	Enhanced understanding of solar PV systems among the general public.
Informed Decision-Making	Consumers making more informed choices regarding solar energy adoption.
Quality Installation Demand	Higher demand for quality solar installations due to increased awareness.
Reduced Misconceptions	Clarity on misconceptions and myths about solar energy.
Engagement and Participation	Active participation of communities in Lebanon’s solar energy transition.
Long-term Sustainability	Promotion of sustainable energy practices through informed public participation.

Table 4: Initiative 1 potential impact

The SEEP will significantly contribute to addressing the knowledge gap in Lebanon’s solar energy sector, ensuring that the public is well-informed and capable of making educated decisions regarding solar energy. This initiative is crucial for cultivating a knowledgeable consumer base and promoting the sustainable growth of solar energy in Lebanon.

2. *Initiative 2: Lebanese Solar Financing and Incentive Program (LSFIP)*

a. <u>Challenge addressed</u>

This initiative addresses the "Limited Financing and Capital" challenge in Lebanon's solar energy sector. Drawing from the German and Californian benchmarks, LSFIP aims to enhance financial accessibility for solar PV systems in Lebanon, focusing on offering diverse financing options and incentives.

b. <u>Description</u>

The Lebanese Solar Financing and Incentive Program (LSFIP) will provide tailored financial solutions to overcome the barriers of high initial investment costs in solar energy. The program includes subsidies, low-interest loans, and a solar leasing model to make solar installations more accessible to a broad range of income groups.

c. Implementation Map

Subsidy Scheme Development: Introduce subsidies for residential and commercial solar installations, reducing the initial cost burden.

Partnership with Financial Institutions: Collaborate with local banks and international financial organizations to offer low-interest solar loans.

Implementation of Solar Leasing Model: Develop a solar leasing framework, allowing homeowners to install solar panels with minimal or no upfront costs.

Awareness Campaign on Financial Benefits: Educate the public about the financial benefits and savings associated with solar energy.

Feedback and Continuous Improvement: Collect feedback from participants and financial institutions to refine the program continuously.

Monitoring and Impact Assessment: Regularly assess the impact of LSFIP on solar energy adoption in Lebanon.

d. Stakeholders and Their Roles

Stakeholder	Role
Ministry of Energy and Water (MEW)	Policy formulation and program oversight.
Lebanese Center for Energy Conservation (LCEC)	Technical support and program implementation guidance.
Local Banks and Financial Institutions	Provision of low-interest loans and financing options.
International Financial Organizations	Support in funding and structuring financial incentives.
Solar Energy Companies	Collaboration in the leasing model and installation services.
Consumers	Beneficiaries of the financial solutions and incentives.
Ministry of Finance	Facilitation of subsidy disbursement and financial management.

Table 5: Initiative 2 stakeholders

e. Potential Impact

Impact	Description
Increased Solar Adoption	Enhanced affordability leading to wider solar PV system adoption.
Financial Accessibility	Making solar energy solutions accessible to diverse income groups.
Long-term Cost Savings	Reduction in electricity bills and reliance on the grid.
Economic Resilience	Strengthening local economies through energy independence.
Environmental Sustainability	Contributing to reduced carbon emissions and cleaner energy.
Job Creation	Growth in the solar industry, creating new employment opportunities.

Table 6: Initiative 2 potential impact

The LSFIP is designed to significantly increase the financial accessibility of solar PV systems in Lebanon. By reducing the initial cost barrier and offering flexible financing options, the program aims to catalyze the adoption of solar energy, contributing to Lebanon's energy independence and environmental sustainability.

3. *Initiative 3: Establishment of the Lebanese Solar Quality and Training Entity (LSQTE)*

a. Challenge Addressed

This initiative addresses two intertwined challenges: "Lack of Training and Craftsmanship" and "Limited Regulation and Enforcement of Installation and Safety Measures" in Lebanon's solar energy sector. Inspired by the regulatory framework of the United States and incorporating elements from the US's licensing and certification systems, the LSQTE aims to enhance both the quality of solar installations and the skill level of solar professionals in Lebanon.

b. Description

The Lebanese Solar Quality and Training Entity (LSQTE) will serve as a central body responsible for improving the quality, safety, and professionalism within the solar PV industry. It will develop and enforce installation standards, certify solar contractors, provide training and accreditation, and conduct regular compliance inspections. Its role can go beyond residential solar PV installations and include industrial and utility-scale installations.

c. Implementation Map

Formation of LSQTE: To be established under the joint supervision of the Ministry of Energy and Water (MEW) and the proposed Electricity Regulatory Authority (ERA).

Standard and Curriculum Development: Develop comprehensive standards for solar installations and a curriculum for solar contractor training.

Training and Certification Programs: Launch training programs for solar contractors, including theoretical and practical components, culminating in certification.

Inspection and Compliance: Conduct inspections to ensure adherence to standards, with penalties for non-compliance.

Public Awareness and Professional Development Campaigns: Promote the benefits of certified installations and ongoing professional development in the solar industry.

Continuous Improvement and Feedback Mechanism: Gather feedback for ongoing refinement of standards, training programs, and inspection processes.

d. Stakeholders and Their Roles

Stakeholder	Role
Ministry of Energy and Water (MEW) and ERA	Oversight, governance, and policy alignment.
Lebanese Center for Energy Conservation (LCEC)	Technical expertise and support in standard and curriculum development.
Educational Institutions	Collaboration in providing training facilities and resources.
Solar Contractors	Participation in training and adherence to LSQTE standards.
Consumers	Engagement in awareness campaigns; opting for certified installations.
Professional Associations	Collaboration in professional development and training programs.

Table 7: Initiative 3 stakeholders

e. Potential Impact

Impact	Description
Enhanced Safety	Reduction in solar PV installation-related accidents and hazards.
Improved Quality	Assurance of efficient, reliable, and durable solar installations.
Consumer Confidence	Increased trust and wider adoption of solar energy solutions.
Market Regulation	Establishment of a fair competitive environment in the solar market.
Job Creation	New opportunities in solar installation, inspection, and regulation sectors.
Compliance with International Standards	Alignment with global best practices, attracting foreign investment and partnerships.

Table 8: Initiative 3 potential impact

The establishment of the LSQTE will be a significant step towards ensuring the sustainable and safe growth of Lebanon's solar energy sector, aligning with international safety standards, and fostering consumer trust in solar technology.

4. Initiative 4: Lebanese Solar Supply Chain Optimization Program (LSSCOP)

a. Challenge addressed

This initiative addresses the challenge of "Burdens in Procurement and Supply Chain Management" in Lebanon's solar energy sector, inspired by First Solar's successful transformation in supply chain management. The LSSCOP is designed to streamline procurement processes, ensure quality material sourcing, and manage logistical complexities effectively.

b. Description

The Lebanese Solar Supply Chain Optimization Program (LSSCOP) will establish a coordinated network for efficient solar equipment procurement, quality assurance, and supply chain management in Lebanon. This program aims to mitigate the challenges arising from high shipping costs, supply delays, and the procurement of substandard materials.

c. Implementation Map

Development of a Centralized Procurement Hub: Establish a government-endorsed hub to centralize procurement and distribution of solar equipment.

Partnerships with Reputable Suppliers: Form strategic partnerships with international and regional suppliers to ensure quality and timely delivery.

Quality Assurance Process: Implement rigorous quality control measures for procured materials.

Optimization of Logistics and Customs Processes: Work with customs authorities to streamline procedures and reduce shipping burdens.

Inventory Management System: Deploy advanced inventory management software for real-time tracking and efficient stock management.

Training and Capacity Building: Provide training programs for stakeholders on best practices in supply chain management.

d. Stakeholders and Their Roles

Stakeholder	Role
Ministry of Energy and Water (MEW)	Oversight and policy formulation for LSSCOP.
Lebanese Center for Energy Conservation (LCEC)	Technical expertise and coordination with suppliers.
Customs and Port Authorities	Streamlining of import processes and reduction of tariffs.

Solar Equipment Suppliers	Provision of high-quality solar equipment and materials.
Solar Installation Companies	Utilization of the procurement hub for equipment acquisition.
Logistics Companies	Efficient handling and transportation of solar equipment.
Financial Institutions	Financial support and facilitation of transactions.

Table 9: Initiative 4 stakeholders

e. <u>Potential Impact</u>

Impact	Description
Reduction in Procurement Costs	Lowered expenses related to equipment procurement and shipping.
Enhanced Equipment Quality	Improved efficiency and durability of solar installations.
Streamlined Supply Chain	Reduced delays and logistical complexities in equipment delivery.
Economic Efficiency	Cost-effectiveness leading to increased investment in solar projects.
Market Stability and Growth	A more stable market environment, encouraging further growth.
Adaptability to Market Changes	Enhanced ability to respond to global supply chain dynamics.

Table 10: Initiative 4 potential impacts

The LSSCOP is set to transform Lebanon's solar sector by addressing the critical challenges in procurement and supply chain management. By optimizing these processes, the program will not only improve the economic feasibility of solar projects but also ensure the consistent quality and reliability of installations across the country.

5. *Initiative 5: Activation and Empowerment of the Electricity Regulatory Authority (ERA)*

a. <u>Challenge addressed</u>

This initiative focuses on the "Lack of Clarity of Governance Structure" in Lebanon's solar energy sector. The key solution is the activation and comprehensive empowerment of the Electricity Regulatory Authority (ERA), taking cues from the centralized governance model exemplified by China's National Energy Administration.

b. Description

The Activation and Empowerment of the Electricity Regulatory Authority (ERA) initiative will solidify ERA's role as the central governing body for Lebanon's solar energy sector. This involves not only activating the ERA but also expanding its scope and authority to effectively manage and regulate the sector, thus creating a more coherent, efficient, and investor-friendly environment.

c. Implementation Map

Legislative Activation of ERA: Advocate for the implementation of Law 462/2002 to officially activate the ERA.

Defining ERA's Scope and Authority: Clearly outline ERA's responsibilities, including policy formulation, standard setting, oversight of solar projects, and coordination with other entities like MEW and LCEC.

Capacity Building for ERA: Equip ERA with the necessary resources, technical expertise, and manpower to fulfill its expanded role.

Stakeholder Engagement and Collaboration: Foster collaboration between ERA and other stakeholders, ensuring alignment of goals and efficient operation.

Public and Investor Engagement: Use ERA as a platform to engage with the public and investors, promoting transparency and trust in Lebanon's solar sector.

Continuous Policy Review and Adaptation: Enable ERA to regularly review and update policies and regulations in response to technological advancements and market dynamics.

d. Stakeholders and Their Roles

Stakeholder	Role
Ministry of Energy and Water (MEW)	Support in policy alignment and providing resources to ERA.
Lebanese Center for Energy Conservation (LCEC)	Technical consultation and collaboration on standards and practices.
Solar Energy Companies	Compliance with regulations and participation in policy development.
Investors and Financial Institutions	Engagement in solar sector development under ERA's regulation.
General Public	Providing feedback and participating in public awareness initiatives.

Table 11: Initiative 5 stakeholders

e. Potential Impact

Impact	Description
Enhanced Regulatory Efficiency	Streamlined governance leading to a more efficient solar sector.
Increased Investor Confidence	Greater transparency and regulatory stability attracting investment.
Unified Policy Implementation	Consistent enforcement of policies and standards across Lebanon.
Advanced Sector Development	Accelerated growth and innovation in the solar sector.
Public Trust and Engagement	Improved public perception and participation in solar initiatives.
Alignment with Global Standards	Positioning Lebanon's solar sector at par with international practices.

Table 12: Initiative 5 potential impact

The activation and empowerment of the ERA is a critical step towards resolving the governance challenges in Lebanon's solar energy sector. By establishing a centralized, authoritative body, this initiative aims to create a regulated and streamlined environment conducive to growth and innovation in the solar industry.

B. Implementation Roadmap for Solar Energy Initiatives in Lebanon

This section outlines a high-level timeline and sequence for the implementation of the proposed initiatives. It presents how these initiatives, when executed in coordination, contribute to establishing a robust and sustainable solar energy system in Lebanon.

1. Timeline and Sequence of Initiatives

As Lebanon embarks on a transformative journey to revitalize its solar energy sector, a strategic and well-structured implementation timeline is crucial. This timeline serves as a roadmap, outlining the sequential rollout of key initiatives designed to address the various challenges within the sector. It provides a clear visualization of the timeframes and overlapping phases of each initiative, ensuring a coordinated and efficient approach. The following table (Table 11) encapsulates this timeline, presenting a concise overview of the initiatives, their respective durations, and primary actions. This systematic planning is vital for achieving the desired outcomes in enhancing Lebanon's solar energy capabilities, ensuring that each step builds upon the progress of the previous ones and contributes to a comprehensive and sustainable solar energy infrastructure. The timeline not only guides the stakeholders through the stages of implementation but also facilitates monitoring and adjustment of the initiatives as they evolve.

Timeframe (Years)	Initiatives	Key Actions
Year 1-2	Activation of ERA	- Immediate steps involve legislative actions to activate and define the scope of ERA. - Initiate capacity building for ERA, including resource allocation and staff training. - ERA begins development of regulatory frameworks and standards for solar energy.
Year 1-3	Establishment of LSQTE	- Concurrent with ERA activation, LSQTE is established to develop quality standards and training programs. - Launch of certification and training programs for solar contractors. - Implementation of inspection and compliance mechanisms.
Year 2-4	Lebanese Solar Financing and Incentive Program (LSFIP)	- After establishing regulatory frameworks, introduce LSFIP, focusing on financial accessibility. - Develop partnerships with financial institutions for low-interest loans and subsidy schemes. - Roll out solar leasing models to reduce upfront costs for homeowners.
Year 3-5	Solar Energy Awareness and Education Program (SEEP)	- Initiate SEEP to increase public knowledge and engagement in solar energy. - Coordinate with educational institutions and local communities for workshops and campaigns. - Continuous public engagement and feedback integration.
Year 3-6	Lebanese Solar Supply Chain Optimization Program (LSSCOP)	- As solar installations increase, LSSCOP streamlines procurement and supply chain processes. - Establish partnerships with suppliers and optimize logistics and customs procedures. - Implement quality control measures and inventory management systems.

Table 13: Implementation Timeline for Solar Energy Initiatives in Lebanon

2. *Integration and Synergy of Initiatives*

Regulatory Foundation: The activation of ERA and establishment of LSQTE provide a regulatory backbone, ensuring quality and safety in installations and workforce competency.

Financial Accessibility and Market Growth: Through LSFIP, financial barriers are reduced, accelerating market growth and public acceptance.

Public Engagement and Education: SEEP plays a crucial role in building public trust and understanding, which is essential for the long-term sustainability of solar initiatives.

Supply Chain Efficiency: LSSCOP ensures the availability and quality of materials, supporting the growing demand resulting from increased public engagement and financial incentives.

Holistic Development: Each initiative complements the others, creating a synergistic effect that drives the overall development of a sustainable and efficient solar energy system in Lebanon.

This roadmap presents a strategic and integrated approach to developing Lebanon's solar energy sector. By carefully sequencing these initiatives and ensuring they build upon each other's strengths, Lebanon can create a cohesive and comprehensive solar energy ecosystem. The success of this roadmap hinges on continuous monitoring, stakeholder engagement, and adaptive management to respond to challenges and leverage emerging opportunities.

C. Risks and Mitigations of Implementing the Solar Energy Initiatives in Lebanon

Implementing solar energy initiatives in Lebanon involves various risks, particularly given the country's unique economic, political, and infrastructural challenges. This section identifies potential risks associated with the proposed initiatives and outlines strategies for their mitigation.

The risks and mitigation strategies may be categorized as follows:

1. *Political and Regulatory Instability*

Risk: Political instability and delays in legislative processes could hinder the activation of ERA and the implementation of other initiatives.

Mitigation: Engage actively with stakeholders across the political spectrum to build broad-based support. Leverage international partnerships for advocacy and support.

2. *Economic Volatility and Funding Shortages*

Risk: Lebanon's economic challenges might limit funding availability for initiatives like LSFIP and LSQTE.

Mitigation: Explore diverse funding sources, including international grants, private investments, and public-private partnerships. Design flexible programs that can adapt to funding constraints.

3. *Insufficient Technical Expertise and Workforce Training*

Risk: Lack of skilled professionals to implement and manage solar energy projects effectively.

Mitigation: Prioritize training and capacity building within LSQTE. Collaborate with educational institutions for workforce development programs.

4. *Public Resistance and Lack of Awareness*

Risk: Public skepticism or resistance to new technologies and changes, hindering SEEP's effectiveness.

Mitigation: Implement comprehensive public awareness campaigns. Involve community leaders in advocacy efforts to enhance public trust and acceptance.

5. *Supply Chain Disruptions*

Risk: Global and regional events, such as pandemics or political conflicts, could disrupt solar equipment supply chains, impacting LSSCOP.

Mitigation: Diversify supply sources and maintain strategic reserves. Develop contingency plans for supply chain disruptions.

6. *Technology Adaptation and Integration Challenges*

Risk: Difficulties in integrating new solar technologies with existing infrastructure and grid systems.

Mitigation: Foster continuous dialogue with technology providers and local engineers. Plan phased technology integration to allow for adaptation and learning.

7. *Quality and Safety Standard Non-compliance*

Risk: Contractors and installers might not adhere to the standards set by LSQTE, risking the quality and safety of installations.

Mitigation: Implement strict enforcement mechanisms, including regular inspections and penalties for non-compliance. Foster a culture of quality and safety in the industry.

Identifying and proactively addressing these risks is crucial for the successful implementation of solar energy initiatives in Lebanon. Effective risk management involves continuous monitoring, stakeholder engagement, and flexibility to adapt strategies in response to changing circumstances. By anticipating challenges and preparing mitigation strategies, Lebanon can ensure the resilient and sustainable development of its solar energy sector.

CHAPTER VI

CONCLUSION

A. Recap of Key Findings and Recommendations

This research has systematically examined the multifaceted challenges and opportunities within Lebanon's solar photovoltaic (PV) sector, amidst its ongoing economic and energy crises. A thorough analysis of the current state of the sector, including benchmarking it against global best practices and conducting a comprehensive review of local and international policies has been conducted. This has culminated in the identification of critical areas requiring intervention and the formulation of strategic initiatives tailored to the Lebanese context. The key findings and strategic recommendations are succinctly outlined below, providing a synthesized overview of the study's essential contributions to the future development of solar PV in Lebanon.

1. Recap of Key Findings

a. <u>Current Landscape of Solar PV in Lebanon:</u>

The study underscored Lebanon's urgent need for renewable energy solutions, particularly solar PV, in response to its profound energy crisis. The analysis revealed a rapid yet unstructured growth in solar PV installations, necessitating regulatory and infrastructural developments.

b. <u>Regulatory and Institutional Deficiencies:</u>

A notable finding was the significant gap in regulatory and institutional frameworks governing the solar PV sector in Lebanon. This gap has led to issues in standardization, safety, and overall sector governance.

c. Economic and Technical Barriers

Financial constraints and technical expertise emerged as primary barriers hindering the broader adoption and effective implementation of solar PV systems in the country.

d. Potential for Sustainable Growth

The research identified a strong potential for sustainable growth in the solar PV sector, contingent upon addressing the existing challenges through strategic interventions.

2. *Recap of Recommendations*

a. Lebanese Solar Quality and Training Entity (LSQTE):

Recommends the establishment of LSQTE to standardize quality assurance and provide comprehensive training and certification for solar PV professionals.

b. Activation and Empowerment of ERA

Advocates for the urgent activation of the Electricity Regulatory Authority (ERA) to centralize governance, streamline policymaking, and enhance regulatory oversight in the solar PV sector.

c. Lebanese Solar Financing and Incentive Program (LSFIP)

Proposes the introduction of LSFIP to improve financial accessibility and incentivize solar PV adoption through subsidies, loans, and leasing models.

d. Solar Energy Awareness and Education Program (SEEP)

Suggests implementing SEEP to increase public awareness, understanding, and support for solar energy initiatives.

e. Lebanese Solar Supply Chain Optimization Program (LSSCOP)

Highlights the need for LSSCOP to address supply chain inefficiencies, ensuring quality and timely availability of solar PV components.

f. Monitoring and Evaluation Framework

Emphasizes establishing a robust framework to monitor and evaluate the progress and impact of the implemented initiatives, enabling adaptive and responsive policymaking.

B. Implications of the Study for the Future of Solar PV in Lebanon

The findings of this research have pivotal implications for the future trajectory of solar photovoltaic (PV) development in Lebanon. While the proposed initiatives are designed for policymakers to consider and potentially implement, the broader implications of this study extend into several key areas of Lebanon's energy sector. They can be summarized as follows:

1. Informing Policy Development

The comprehensive analysis of Lebanon's solar PV sector, along with the global benchmarking, provides valuable insights for policymakers. The study offers a detailed understanding of the sector's challenges and opportunities, which can inform the development of more effective solar energy policies and strategies.

2. Facilitating Regulatory Reforms

The research highlights the critical need for regulatory reforms, particularly in establishing a coherent governance structure, such as the proposed activation of the Electricity Regulatory Authority (ERA). By outlining the benefits of such reforms, the study can guide legislators and regulators in enacting necessary changes to foster a conducive environment for solar energy growth.

3. Guiding Investment Priorities

The findings underscore the importance of targeted investments, not only in solar technology but also in infrastructure, training, and public awareness. This can guide both public and private investment decisions towards areas that will yield the most significant impact on the sector's development.

4. Encouraging Stakeholder Collaboration

The study emphasizes the need for collaboration among various stakeholders, including government entities, private sector participants, financial institutions, and educational bodies. Such collaborative efforts are essential for addressing the multifaceted challenges of Lebanon’s solar PV sector.

5. *Enhancing Public Awareness and Engagement*

The research identifies a significant gap in public awareness and understanding of solar energy. The implications of this finding highlight the need for comprehensive awareness and education campaigns, which are crucial for increasing public acceptance and support for solar energy initiatives.

6. *Shaping Future Research Agendas*

This study lays the groundwork for future research in the field, identifying areas that require further exploration, such as the integration of solar PV with other renewable energy sources, the socio-economic impacts of solar energy expansion, and environmental considerations.

7. *Global Integration and Best Practices Adoption*

The international benchmarking component of this study provides a framework for aligning Lebanon's solar sector with global best practices. This alignment is vital for the sector's technological advancement, quality assurance, and overall competitiveness in the global renewable energy landscape.

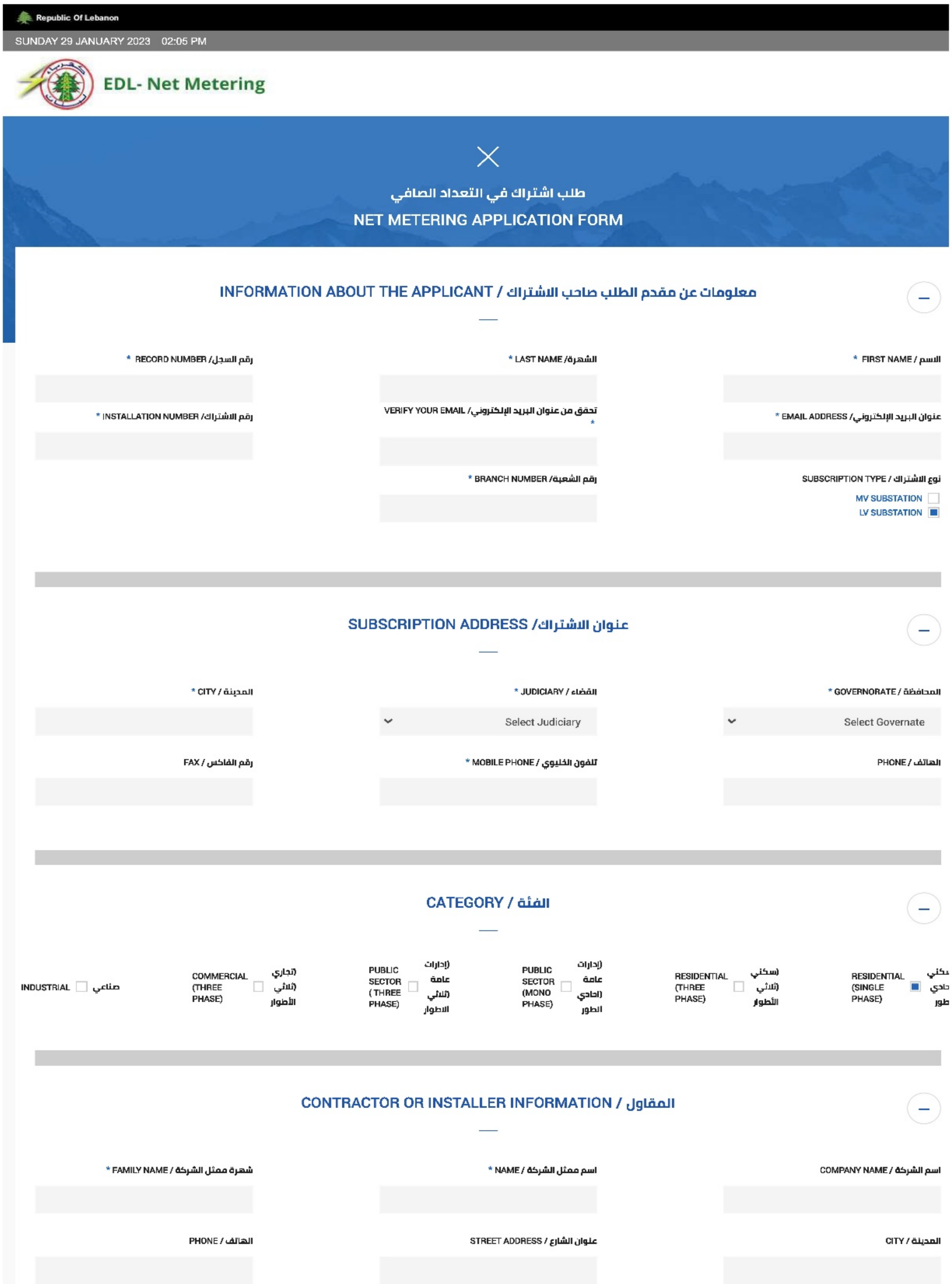
In essence, this research provides a strategic perspective on the development of the solar PV sector in Lebanon, with broad implications for policy formulation, sector governance, investment strategies, and stakeholder collaboration. While the direct implementation of the proposed initiatives lies with policymakers and industry players, the study contributes to a more informed, structured, and strategic approach to fostering solar energy development in Lebanon.

C. Future Research Directions

In conclusion, this thesis represents a comprehensive endeavor to address the critical challenges facing Lebanon's solar photovoltaic (PV) sector amidst its complex economic and energy landscape. The proposed initiatives, grounded in rigorous analysis and global benchmarking, offer a strategic pathway towards revitalizing and sustainably developing this vital sector. By advocating for systemic reforms, enhanced regulatory frameworks, targeted financial mechanisms, and widespread public engagement, this study contributes to shaping a future where solar energy is not only a cornerstone of Lebanon's energy strategy but also a catalyst for economic resilience and environmental sustainability. As Lebanon stands at crossroads, the findings and recommendations of this thesis offer a blueprint for action, providing policymakers, industry stakeholders, and the society with the tools to harness the immense potential of solar energy. In harnessing this potential, Lebanon can not only address its immediate energy challenges but also lay the foundation for a brighter, more sustainable future.

APPENDIX

Appendix I



Republic Of Lebanon

SUNDAY 29 JANUARY 2023 02:05 PM

EDL- Net Metering

طلب اشتراك في التعداد الصافي

NET METERING APPLICATION FORM

INFORMATION ABOUT THE APPLICANT / معلومات عن مقدم الطلب صاحب الاشتراك

* FIRST NAME / الإسم

* LAST NAME / الشهرة

* RECORD NUMBER / رقم السجل

* EMAIL ADDRESS / عنوان البريد الإلكتروني

VERIFY YOUR EMAIL / تحقق من عنوان البريد الإلكتروني *

* INSTALLATION NUMBER / رقم الاشتراك

SUBSCRIPTION TYPE / نوع الاشتراك

MV SUBSTATION

LV SUBSTATION

* BRANCH NUMBER / رقم الشعبة

SUBSCRIPTION ADDRESS / عنوان الاشتراك

* GOVERNORATE / المحافظة

Select Governate

* JUDICIARY / القضاء

Select Judiciary

* CITY / المدينة

PHONE / الهاتف

* MOBILE PHONE / تلفون الخليوي

FAX / رقم الفاكس

CATEGORY / الفئة

RESIDENTIAL (SINGLE PHASE) سكني (احادي الطور)

RESIDENTIAL (THREE PHASE) سكني (ثلاثي الأطوار)

PUBLIC SECTOR (MONO PHASE) إدارات عامة (أحادي الطور)

PUBLIC SECTOR (THREE PHASE) إدارات عامة (ثلاثي الأطوار)

COMMERCIAL (THREE PHASE) تجاري (ثلاثي الأطوار)

INDUSTRIAL صناعي

CONTRACTOR OR INSTALLER INFORMATION / المقاول

COMPANY NAME / اسم الشركة

* NAME / اسم ممثل الشركة

* FAMILY NAME / شهرة ممثل الشركة

CITY / المدينة

STREET ADDRESS / عنوان الشارع

PHONE / الهاتف

* MOBILE PHONE / الخليوي | * EMAIL ADDRESS / البريد الالكتروني | FAX / رقم الفاكس

RENEWABLE ENERGY SOURCE INFORMATION / معلومات مصدر الطاقة المتجددة

* ENERGY SOURCE / مصدر الطاقة

- [x] SOLAR شمسي
- [ ] WIND ريح
- [ ] HYDRO المائية
- [ ] BIOENERGY الطاقة الحيوية
- [ ] OTHERS (SPECIFY) أخرى (حدد)

* ENERGY SOURCE MANUFACTURER / صانع مصدر الطاقة

* ENERGY SOURCE MODEL / طراز مصدر الطاقة

*RENEWABLE ENERGY SOURCE DATASHEET /بيانات مصدر الطاقة المتجددة

UPLOAD DOCUMENT

* POWER GENERATOR TYPE / نوع مولد الطاقة

- [x] DIRECT CURRENT (DC) التيار المباشر
- [ ] SYNCHRONOUS متزامن
- [ ] INDUCTION الحث الكهرومغناطيسي
- [ ] OTHERS (SPECIFY) أخرى

PV MODULES COMPLIANCE STANDARDS / المعايير الملتزمة بها اللوائح الكهروضوئية

DESIGN QUALIFICATION AND TYPE APPROVAL (SELECT AT LEAST ONE)	SAFETY QUALIFICATION (SELECT AT LEAST ONE)	SALT MIST CORROSION TESTING OF PHOTOVOLTAIC (SELECT AT LEAST ONE)	PROTECTION AGAINST ELECTRIC SHOCK (SELECT AT LEAST ONE)
IEC 61646	IEC 61730-1 & IEC 61730-2	IEC 61701	IEC 60364-4-41
IEC 61215	OTHERS (SPECIFY)	OTHERS (SPECIFY)	OTHERS (SPECIFY)
OTHERS (SPECIFY)		IEC 62716	

PV MODULE CERTIFICATES FOR ALL REQUIRED STANDARDS IN A ZIPPED FILE / الرجاء ارفاق شهادة اللوائح الكهروضوئية لكل المعايير المطلوبة

UPLOAD DOCUMENT

INVERTER (1) INFORMATION / معلومات عن العاكس (1)

* MANUFACTURER / صانع

* RATED CAPACITY / السعة المقدرة

(KW)

* # OF PHASES / عدد الاطوار

* MODEL / طراز

* OUTPUT VOLTAGE / الجهد الكهربى

(V)

STORAGE BATTERY? / تخزين البطارية في النظام؟
* IN THE SYSTEM

☐ YES نعم ☒ NO لا

ADDITIONAL INVERTER (1) INFORMATION / معلومات عن العاكس (1)

* INVERTER TYPE / لوع مولد الطاقة

☒ GRID-TIED INVERTER (ON-GRID INVERTER) ☐ OFF-GRID INVERTER ☐ HYBRID INVERTER

* INVERTER DATASHEET / بيانات العاكس

UPLOAD DOCUMENT

INVERTER (1) COMPLIANCE STANDARD / معايير العاكس (1)

GRID CONNECTION (SELECT AT LEAST ONE)

- ☐ G59/3 (>16A)
- ☐ IEC 61727
- ☐ IEC 62116
- ☐ VDE-ARN 4105
- ☐ AS/NZS4777.1 AND AS/NZS4777.2
- ☐ G83/2 (UP TO 16A)
- ☐ EN 50438 (I <16A)
- ☐ OTHERS (SPECIFY)

VOLTAGE FLUCTUATIONS (SELECT AT LEAST ONE)

- ☐ IEC 61000-3-11 (I ≤ 75A)
- ☐ IEC 61000-3-5 (I>75A)
- ☐ OTHER (SPECIFY)
- ☐ IEC 61000-3-3 (RATED CURRENT ≤16 A PER PHASE)

HARMONICS (SELECT AT LEAST ONE)

- ☐ IEC 61000-3-2 (I<=16A)
- ☐ IEC 61000-3-4 (I>16A)
- ☐ OTHERS (SPECIFY)
- ☐ IEC 61000-3-12 (16A<CURRENT ≤ 75A)

GENERAL SAFETY REQUIREMENTS (SELECT AT LEAST ONE)

- ☐ AS/NSZ3100
- ☐ UL 1741
- ☐ IEC 62109-1 AND IEC 62109-2
- ☐ OTHERS (SPECIFY)

INVERTER CERTIFICATE FOR ALL REQUIRED STANDARDS IN A ZIPPED FILE / الرجاء ارفاق شهادة العاكس لكل المعايير المطلوبة

UPLOAD DOCUMENT

ADD NEW INVERTER

LOCATION AND THE GENERAL SPECIFICATIONS OF THE INSTALLED SYSTEM / الموقع ومعلومات عامة عن النظام

* SITE GPS LOCATION / موقع

* RATED CAPACITY / القدرة المركبة

(KW)

* OUTPUT VOLTAGE / الجهد الكهربائي

(V)

OF PHASES / عدد الاطوار

ELECTRICITY DEMAND / الاستهلاك السنوي للطاقة

(KWH/YEAR)

ENERGY PRODUCTION / إنتاج الطاقة/سنة

(KWH/YEAR)

* SPECIAL AGREEMENT FOR THE RENEWABLE ENERGY SUBSCRIBERS AND PRODUCERS FGSDF/ إتفاقية خاصة بمنتجي ومشتركي الطاقة المتجددة

PLEASE DOWNLOAD THE BELOW - PRINT, FILL, SIGN AND ATTACH / الرجاء تحميل الوثائق بالأسفل، طباعتها، امضائها وارفاقها

DOWNLOAD AGREEMENT | UPLOAD DOCUMENT

*COPY OF THE ID OF THE HOLDER OF THE SUBSCRIPTION / صورة عن هوية صاحب الاشتراك

UPLOAD DOCUMENT

* COPY OF THE APPLICANT'S BILL OR COPY OF THE AB / AB صورة عن فاتورة صاحب الإشتراك أو قسيمة ال

UPLOAD DOCUMENT

COMMERCIAL CIRCULAR - IF THE APPLICANT IS A COMPANY OR AN INSTITUTION / الاذاعة التجارية- اذا كان مقدم الطلب شركة او مؤسسة

UPLOAD DOCUMENT

* DETAILED SLD

UPLOAD DOCUMENT

* CHECKLIST / قائمة التدقيق

DOWNLOAD CHECKLIST | UPLOAD DOCUMENT

GRID IMPACT ASSESSMENT AND PERFORMANCE RATIO (IF NEEDED)/ (تقييم التأثير على الشبكة ونسبة الأداء (اذا لزم الأمر

UPLOAD DOCUMENT

* REQUIRED FIELDS

SUBMIT

LEBANESE REPUBLIC MINISTRY OF ENERGY AND WATER

LCEC

This project is funded by the European Union

UNDP

Appendix II

Prescriptive Solar Photovoltaic Installation Checklist

2019 Oregon Structural Specialty Code (OSSC) Compliance

Use this checklist to demonstrate compliance with the prescriptive photovoltaic (PV) requirements of Sections 3111.3.5.3 and 3111.3.4.8 of the Oregon Structural Specialty Code (OSSC). Separate electrical permits are required for the installations.

PART I – PROPERTY OWNER INFORMATION

Property owner name:		Phone number:
Installation address:		
City:	State: Oregon	ZIP:
Structure on which modules are to be installed:		
Installer: ☐ Contractor ☐ Owner (If owner, skip to Part III)		

PART II – CONTRACTOR INFORMATION

Contractor name:	Phone number:
Email address:	
BCD business license #:	Contractor's CCB#:

PART III – STRUCTURAL CRITERIA

Roof structure requirements

If "No" is selected for any item below, or if the supporting structure is a manufactured dwelling, the project ***may not*** *be submitted using the prescriptive path.*

Check the appropriate boxes for each item as it applies to the project.

- Structure is classified Risk Category I or II in accordance with OSSC 1604.5:______________ ☐ Yes ☐ No
- Structure is of *conventional light-frame construction*:______________ ☐ Yes ☐ No
- Supporting roof framing is one of the following:______________ ☐ Yes ☐ No
  (*check one*) ☐ Pre-engineered trusses spaced ≤ 24 inches o.c.; **or**
  ☐ Rafters spaced ≤ 24 inches o.c. and spans comply with OSSC 2308.7.2 **or** ORSC R802.5, respectively
- Ground snow load does not exceed maximum load:______________ ☐ Yes ☐ No
  (*check one*) ☐ ≤ 50 psf for structures under the ORSC, **or** ☐ ≤ 70 psf for structures under the OSSC
- The basic design wind speed does not exceed the following:______________ ☐ Yes ☐ No
  (*check one*) ☐ ≤ 120 mph in Wind Exposure Category C for structures under the OSSC; **or**
  ☐ ≤ 135 mph in Wind Exposure Category B for structures under the OSSC; **or**
  ☐ ≤ 135 mph in Wind Exposure Category C for structures under the ORSC
- Roofing materials are metal, single-layer wood shingle or shake, or not more than two layers of composition shingle:______________ ☐ Yes ☐ No
- Module height is less than 18 inches from the top of the module to the roof surface and complies with Figures 3111.3.5.3(1) and 3111.3.5.3(2):______________ ☐ Yes ☐ No

BCD Building Codes Division
Department of Consumer and Business Services

Published by Building Codes Division – Aug. 18, 2021

PART III – STRUCTURAL CRITERIA (continued)

Loading requirements

Check the appropriate boxes for each item associated with the selected attachment method.

Attachment 1: PV modules or racking is attached directly to the **roof framing or blocking**:

- Combined weight of PV modules and racking is not more than 4.5 psf:__________ Yes No
- Spacing of PV modules or racking complies with one of the following:__________ Yes No

(*check one*) ≤ 48 inches in any direction; **or**
≤ 24 inches in any direction where the following are true:

- ☐ Ground snow load is more than 36 psf
- ☐ Panels are located within 3 feet of a roof edge, hip, eave, or ridge
- ☐ Basic design wind speed is greater than 120 mph in Wind Exposure Category B
- ☐ Basic design wind speed is greater than 110 mph in Wind Exposure Category C

**If this is the appropriate attachment method and "No" is selected for any of the items above, the project may not be submitted using the prescriptive path.*

Attachment 2: PV modules or racking is attached directly to **standing seam metal panels**:

- Combined weight of PV modules and racking is not more than 4.5 psf:__________ Yes No
- **Clamps** comply with the following requirements:
  - ☐ Provide the following, allowable uplift capacity:__________ Yes No

    (*check one*) Not less than 115 pounds and spaced at 60 inches o.c. or less; **or**
    Not less than 75 pounds and spaced at 48 inches o.c. or less.
  - ☐ Spacing between metal panel seams is not more than 24 inches__________ Yes No
  - ☐ Spacing along a metal panel seam is not more than 60 inches__________ Yes No
- **Metal roofing panels** comply with the following requirements:
  - ☐ Panel thickness is 26 gauge steel, minimum__________ Yes No
  - ☐ Panel width is 18 inches or less__________ Yes No
  - ☐ Attached with at least #10 screws at 24 inches o.c.__________ Yes No
  - Installed over minimum ½-inch nominal wood structural panels attached to framing with 8d nails at 6 inches o.c. at panel edges and 12 inches o.c. field nailing__________ Yes No

**If this is the appropriate attachment method and "No" is selected for any of the items above, the project may not be submitted using the prescriptive path.*

PART IV – ROOF DESIGN SITE PLAN

Roof design requirements

- Attach a simple structural plan showing the roof framing (rafter size, type, and spacing) and PV system racking attachment.
- System must be shown in sufficient detail to assess whether the requirements of Section 3111.3.5.3 have been met.
- The structural plan must be on 8.5-inch x 11-inch or larger paper.

PART V – PV MODULES

Manufacturer:
Model number:
Listing agency:

PART VI – PATHWAYS AND CLEARANCES

Pathway and clearance requirements

- Using the grid below or an attached 8.5-inch x 11-inch or larger paper, provide a simple drawing, indicating the location of the PV system in relation to buildings, structures, property lines, and, as applicable, flood hazard areas.
- The drawing must be shown in sufficient detail to assess whether the *pathway* requirements of Section 3111.3.4.8 or one of the exceptions have been met.

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