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HARNESSING RENEWABLE ENERGY FOR SOCIAL AND TERRITORIAL EQUITY IN THE EUROMED REGION: DECENTRALIZED SOLAR ENERGY AS A CATALYST FOR COMMUNITY EMPOWERMENT AND CLIMATE ACTION

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CONTENTS

ABSTRACT

This paper examines the potential of decentralized solar energy (DSE) systems to advance social and territorial equity in the Euromed region, covering Southern Europe, North Africa, and parts of the Middle East. Against a backdrop of climate vulnerability, persistent energy poverty, and socio-economic disparities, decentralized solar solutions represent a powerful lever for inclusive climate action. Through an integrated analysis of case studies (Spain, Tunisia, Morocco, Lebanon) and comparative policy review, this study explores how locally owned, small-scale energy systems can enhance energy access, foster economic empowerment, and strengthen community resilience.

DSE systems are well-suited to the region's abundant solar resources and its uneven energy infrastructure. They provide reliable, affordable, low-carbon power to marginalized communities that remain underserved by centralized grids. The case studies reveal measurable social benefits from enhanced community participation and improved living standards to job creation and capacity building. Economic gains include reduced electricity costs, increased income stability, and strengthened local value chains, particularly in agriculture and small enterprises. Environmentally, decentralized systems significantly reduce GHG emissions and dependence on fossil fuel, contributing directly to the region's climate commitments.

However, the research also identifies critical barriers limiting widespread adoption: high upfront investment costs, insufficient financial instruments, regulatory fragmentation, limited local technical capacity, and challenges related to battery lifespan, recycling, and end-of-life management of solar equipment. In low-demand rural areas, system viability can be constrained by limited economic activity, underscoring the need for integrated development strategies.

To address these gaps, the study recommends:

- Simplifying regulatory frameworks to reduce permitting burdens and facilitate grid integration for small-scale and community-owned systems;
- Expanding financial incentives through grants, concessional loans, cooperative financing, and public-private mechanisms;
- Investing in local skills and workforce development, especially in installation, maintenance, digital energy management, and storage technologies;
- Promoting technological innovation, including next-generation storage and circular-economy frameworks for PV and battery recycling;
- Strengthening regional cooperation, notably through bottom-up and top-down initiatives supporting evidence-based policymaking and bottom-up implementation.

Overall, decentralized solar energy constitutes a strategic opportunity to advance a fair, resilient, and low-carbon energy transition in the Euromed region. By empowering communities, reducing territorial inequalities, and

supporting climate objectives, DSE systems can become a cornerstone of an inclusive Mediterranean energy future—provided that policy, financial, and technical frameworks are adapted to unlock their full potential.

RÉSUMÉ

Cet article examine le potentiel des systèmes solaires décentralisés (Decentralized Solar Energy – DSE) pour promouvoir l'équité sociale et territoriale dans la région euro-méditerranéenne (Euromed), couvrant l'Europe du Sud, l'Afrique du Nord et certaines parties du Moyen-Orient. Dans un contexte marqué par une forte vulnérabilité climatique, une pauvreté énergétique persistante et des inégalités socio-économiques, les solutions solaires décentralisées constituent un levier puissant pour une action climatique inclusive. À travers une analyse intégrée d'études de cas (Espagne, Tunisie, Maroc, Liban) et une revue comparative des politiques publiques, cette étude explore la manière dont des systèmes énergétiques locaux et de petite échelle peuvent améliorer l'accès à l'énergie, favoriser l'autonomisation économique et renforcer la résilience des communautés.

Les systèmes DSE sont particulièrement adaptés aux abondantes ressources solaires de la région ainsi qu'à l'inégale répartition de ses infrastructures énergétiques. Ils fournissent une énergie fiable, abordable et à faible émission de carbone aux communautés marginalisées qui restent insuffisamment desservies par les réseaux centralisés. Les études de cas mettent en évidence des bénéfices sociaux mesurables, allant d'une participation communautaire accrue et d'une amélioration des conditions de vie à la création d'emplois et au renforcement des capacités. Les retombées économiques incluent une réduction des coûts de l'électricité, une plus grande stabilité des revenus et le renforcement des chaînes de valeur locales, en particulier dans l'agriculture et les petites entreprises. Sur le plan environnemental, les systèmes décentralisés réduisent significativement les émissions de gaz à effet de serre et la dépendance aux combustibles fossiles, contribuant directement aux engagements climatiques de la région.

Toutefois, la recherche identifie également des obstacles majeurs freinant leur adoption à grande échelle : des coûts d'investissement initiaux élevés, des instruments financiers insuffisants, une fragmentation réglementaire, des capacités techniques locales limitées, ainsi que des défis liés à la durée de vie des batteries, à leur recyclage et à la gestion de fin de vie des équipements solaires. Dans les zones rurales à faible demande, la viabilité des systèmes peut être limitée par une activité économique restreinte, ce qui souligne la nécessité de stratégies de développement intégrées.

Afin de combler ces lacunes, l'étude recommande :
- La simplification des cadres réglementaires afin de réduire les charges administratives et de faciliter l'intégration au réseau des systèmes de petite taille et détenus par les communautés ;
- L'élargissement des incitations financières à travers des subventions, des prêts concessionnels, des mécanismes de financement coopératif et des partenariats public-privé ;

- L'investissement dans le développement des compétences et de la main-d'œuvre locales, notamment dans l'installation, la maintenance, la gestion numérique de l'énergie et les technologies de stockage ;
- La promotion de l'innovation technologique, y compris les solutions de stockage de nouvelle génération et les cadres d'économie circulaire pour le recyclage des panneaux photovoltaïques et des batteries ;
- Le renforcement de la coopération régionale, notamment par des initiatives ascendantes et descendantes soutenant l'élaboration de politiques fondées sur des données probantes et leur mise en œuvre locale.

Dans l'ensemble, l'énergie solaire décentralisée constitue une opportunité stratégique pour promouvoir une transition énergétique juste, résiliente et à faible émission de carbone dans la région euro-méditerranéenne. En autonomisant les communautés, en réduisant les inégalités territoriales et en soutenant les objectifs climatiques, les systèmes DSE peuvent devenir une pierre angulaire d'un avenir énergétique méditerranéen inclusif, à condition que les cadres politiques, financiers et techniques soient adaptés afin d'en libérer tout le potentiel.

الملخص

في (Decentralized Solar Energy – DSE) تبحث هذه الورقة في إمكانات أنظمة الطاقة الشمسية اللامركزية تعزيز العدالة الاجتماعية والمجالية في منطقة اليورو-متوسط، التي تشمل جنوب أوروبا وشمال إفريقيا وأجزاء من الشرق الأوسط. وفي ظل سياق يتسم بارتفاع مستويات الهشاشة المناخية، واستمرار فقر الطاقة، واتساع الفجوات الاجتماعية والاقتصادية، تمثل حلول الطاقة الشمسية اللامركزية أداة فعّالة لتحقيق عمل مناخي شامل. ومن خلال تحليل متكامل لدراسات حالة من إسبانيا وتونس والمغرب ولبنان، إلى جانب مراجعة مقارنة للسياسات العامة، تستكشف هذه الدراسة كيف يمكن لأنظمة الطاقة المحلية صغيرة النطاق والمملوكة محليًا أن تعزز الوصول إلى الطاقة، وتدعم التمكين الاقتصادي، وتقوي قدرة المجتمعات على الصمود.

تُعد أنظمة الطاقة الشمسية اللامركزية مناسبة بشكل كبير للموارد الشمسية الوفيرة في المنطقة، وكذلك للطابع غير المتكافئ للبنية التحتية للطاقة فيها. فهي توفر طاقة موثوقة، ميسورة التكلفة، ومنخفضة الانبعاثات الكربونية للمجتمعات المهمشة التي لا تزال تعاني من ضعف الخدمات في الشبكات المركزية. وتُظهر دراسات الحالة فوائد اجتماعية ملموسة، تتراوح بين تعزيز مشاركة المجتمعات المحلية وتحسين مستويات المعيشة، وصولًا إلى خلق فرص عمل وبناء القدرات. وتشمل المكاسب الاقتصادية خفض تكاليف الكهرباء، وزيادة استقرار الدخل، وتعزيز سلاسل القيمة المحلية، ولا سيما في قطاعي الزراعة والمشروعات الصغيرة. أما على الصعيد البيئي، فتسهم الأنظمة اللامركزية بشكل كبير في خفض انبعاثات غازات الدفيئة وتقليل الاعتماد على الوقود الأحفوري، بما يدعم بشكل مباشر الالتزامات المناخية للمنطقة.

ومع ذلك، تحدد الدراسة أيضًا عددًا من العوائق الرئيسية التي تعرقل التوسع الواسع في اعتماد هذه الأنظمة، من بينها ارتفاع تكاليف الاستثمار الأولية، ونقص الأدوات التمويلية الملائمة، وتجزؤ الأطر التنظيمية، وضعف القدرات التقنية المحلية، إضافة إلى التحديات المرتبطة بعمر البطاريات، وإعادة تدويرها، وإدارة معدات الطاقة الشمسية في نهاية عمرها التشغيلي. وفي المناطق الريفية ذات الطلب المنخفض، قد تتأثر جدوى هذه الأنظمة بمحدودية النشاط الاقتصادي، مما يبرز الحاجة إلى استراتيجيات تنموية متكاملة.

ولمعالجة هذه الفجوات، توصي الدراسة بما يلي:

- تبسيط الأطر التنظيمية للحد من الأعباء الإجرائية وتسهيل دمج الأنظمة الصغيرة والمملوكة مجتمعيًا في الشبكات الكهربائية؛
- توسيع الحوافز المالية من خلال المنح، والقروض الميسرة، وآليات التمويل التعاوني، والشراكات بين القطاعين العام والخاص؛
- الاستثمار في تنمية المهارات وبناء القدرات المحلية، لا سيما في مجالات التركيب والصيانة، والإدارة الرقمية للطاقة، وتقنيات التخزين؛
- تعزيز الابتكار التكنولوجي، بما في ذلك تقنيات التخزين المتقدمة وأطر الاقتصاد الدائري لإعادة تدوير الألواح الشمسية والبطاريات؛
- تعزيز التعاون الإقليمي، ولا سيما عبر مبادرات تصاعدية وتنازلية تدعم صياغة السياسات القائمة على الأدلة وتنفيذها على المستوى المحلي.

بوجه عام، تمثل الطاقة الشمسية اللامركزية فرصة استراتيجية لدفع انتقال طاقي عادل، ومرن، ومنخفض الكربون في منطقة اليورو-متوسط. ومن خلال تمكين المجتمعات المحلية، وتقليص الفوارق المجالية، ودعم الأهداف المناخية، يمكن لأنظمة الطاقة الشمسية اللامركزية أن تشكل ركيزة أساسية لمستقبل طاقي متوسطي شامل، شريطة تكييف الأطر السياسية والمالية والتقنية بما يتيح إطلاق كامل إمكاناتها.

INTRODUCTION

EMPOWERING SUSTAINABLE DEVELOPMENT IN THE EUROMED REGION

The Euromed region, spanning Southern Europe, North Africa, and parts of the Middle East, is positioned at the intersection of critical environmental and socio-economic challenges[1]. Climate change has amplified the region's vulnerabilities, intensifying water scarcity, economic disparities, and resource inequities[2]. As a region with abundant solar resources, the Euromed area holds vast potential to lead the transition to renewable energy, particularly through decentralized solar energy systems[3]. This approach could not only mitigate climate impacts but also address socio-economic inequities, fostering inclusive and sustainable development.

The need for transformative action is pressing. Rising temperatures and the growing frequency of extreme weather events threaten livelihoods, ecosystems, and regional stability. Simultaneously, many communities in the Euromed region, particularly in rural or underserved areas, lack access to affordable and reliable energy. This dual challenge of environmental and social vulnerability underscores the urgency of adopting solutions that are both sustainable and inclusive. Decentralized solar energy systems stand out as a viable path forward, enabling localized energy generation and reducing dependence on centralized infrastructures that often exclude marginalized populations.

Such systems align closely with global and regional frameworks aimed at sustainable development. The European Green Deal, with its goal of achieving net-zero greenhouse gas emissions by 2050, emphasizes the need for a fair and inclusive energy transition[4]. Similarly, the Union for the Mediterranean's 2030 GreenerMed Agenda[5] prioritizes low-carbon economies, resource efficiency, and social equity across the Mediterranean basin. These frameworks recognize that environmental sustainability must be paired with socio-economic strategies to build resilience and reduce inequalities. Decentralized solar energy (DSE) offers numerous benefits. It reduces greenhouse gas emissions, contributes to energy security, and provides communities with control over their energy resources. For underserved areas, these systems are particularly transformative, addressing energy poverty while creating economic opportunities through job creation in installation, maintenance, and energy management. By fostering local participation, decentralized energy models also strengthen territorial cohesion and empower communities to take ownership of their development paths.

[1] Plan Bleu, State of the Environment and Development in the Mediterranean (SoED), 2020.

[2] Mediterranean Experts on Climate and Environmental Change (MedECC), Mediterranean Assessment Report (MAR1), 2020.

[3] ECCO Climate, Setting the scene for an interconnected, renewable mediterranean energy system, 2024.

[4] European Commission, Le pacte vert pour l'Europe - Commission européenne, 2019-2024.

[5] Union for the Mediterranean (UfM), Towards 2030: Agenda for a Greener Med, 2022.

Realizing the potential of decentralized solar systems requires innovative governance, North-South collaboration and capacity building. Cross-national cooperation programs like the Interreg Next-Med[6] and Euro-MED[7] demonstrate the value of collaborative approaches that bring together policymakers, businesses, and local communities around the Mediterranean region. These initiatives offer resources and training to facilitate the adoption of renewable energy, ensuring that solutions are adapted to the specific needs of diverse stakeholders across the region. By integrating technical innovation with social inclusion, such projects exemplify how climate action can be a catalyst for broader development goals.

The proposed research aims to explore the transformative potential of decentralized solar energy in the Euromed region. By focusing on community-centered energy solutions, it seeks to propose pathways for achieving sustainable and equitable growth. This approach aligns with the broader objectives of global frameworks such as the United Nations 2030 Agenda and its Sustainable Development Goals, which emphasize the interconnection between environmental action, economic empowerment, and social inclusion.

Tackling Climate Action and Promoting Equity

The Euromed region stands at the confluence of two urgent and interconnected challenges: accelerating climate action[8] to address worsening environmental conditions and fostering social and territorial equity[9] to ensure stability and resilience. This dual imperative arises from the region's unique vulnerabilities to climate change, coupled with pronounced socio-economic and geographic disparities.

On one hand, accelerating climate action is critical to preserving fragile ecosystems and reducing carbon emissions. The Mediterranean region is already experiencing the impacts of rising temperatures, water scarcity, and resource depletion, which exacerbate socio-economic vulnerabilities such as food insecurity and inflation. Without decisive action, these pressures risk further destabilizing communities and undermining sustainable development across the region.

At the same time, the Euromed region is characterized by stark inequalities in social and territorial development. Rural and remote communities, particularly those disconnected from central energy grids, often lack access to reliable electricity, employment, and essential services. These disparities not only restrict opportunities for millions of residents but also impede the region's ability to achieve a cohesive transition to renewable energy systems and sustainable growth[10].

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[6] Interreg NEXT MED, Official Website of the Interreg Next-Med Programme.

[7] Interreg Euro-MED, Programme Interreg Euro-MED.

[8] Mediterranean Experts on Climate and Environmental Change (MedECC), Mediterranean Assessment Report (MAR1), 2020.

[9] Plan Bleu & UNEP/MAP, State of the Environment and Development in the Mediterranean (SoED), 2020.

[10] European Economic and Social Committee, Renewable energy in Euromed - Filtered results | EESC, 2021.

Addressing these dual challenges requires innovative and inclusive solutions. Renewable energy, particularly decentralized solar power, emerges as a strategic tool for bridging these divides. Unlike centralized energy systems that often bypass marginalized areas, decentralized solar energy allows for localized production and distribution, empowering communities to generate and manage their own power. Such systems not only provide reliable and affordable energy but also create economic opportunities by involving local actors in installation, maintenance, and governance. They are particularly effective in underserved regions, where they can enhance access to electricity while simultaneously reducing greenhouse gas emissions[11].

Moreover, decentralized solar initiatives have the potential to promote social justice by directly involving communities in decision-making processes. By fostering local ownership and management, these systems not only distribute economic benefits more equitably but also strengthen social cohesion and regional resilience. This inclusive approach aligns with broader global objectives, including the United Nations Sustainable Development Goals, which emphasize the need for climate action that is equitable and leaves no one behind[12].

The research focuses on the transformative role of decentralized solar energy in addressing these twin imperatives. By examining energy models that are adaptable to diverse local contexts, the study aims to demonstrate how renewable energy can serve as a vehicle for both environmental sustainability and socio-economic equity. This integrated approach offers a pathway for the Euromed region to simultaneously mitigate climate impacts and foster inclusive development, paving the way for a resilient and equitable energy future.

Decentralized Solar Energy Systems

Decentralized solar energy systems represent a transformative solution to the dual challenges of climate action and socio-economic inequity, particularly in regions like Euromed. Unlike traditional centralized energy models, where electricity is generated at large facilities and distributed through extensive grids, decentralized solar systems generate energy locally. This community-centered approach is especially well-suited for addressing the unique environmental and social contexts of the Mediterranean region.
One of the most significant advantages of decentralized solar energy systems is their capacity to provide reliable power to rural and remote communities that have historically been excluded from traditional energy infrastructure. In these areas, extending centralized grid networks is often prohibitively expensive and logistically challenging. Decentralized systems, such as rooftop solar panels or small solar farms, can bypass these barriers, delivering clean energy directly to underserved populations while reducing dependency on fossil fuels[13].

[11] A.T. Carabajal, A. Orsot, M.P.E. Moudio, T. Haggai, C.J. Okonkwo, G.T. Jarrard III, and N.S. Selby, Social and Economic Impact Analysis of Solar Mini-Grids in Rural Africa: A Cohort Study from Kenya and Nigeria, 2023.

[12] United Nations, Sustainable Development Goals.

[13] The Guardian, Solar power to the people: how the sun is bringing light – and TV – to Amazon villages, 2024.

The adaptability of decentralized solar systems is another critical factor in their potential. These systems can be tailored to the specific needs and resources of individual communities. For instance, small-scale solar installations can support agricultural activities through solar-powered irrigation, or provide electricity for schools and health clinics. This adaptability ensures that energy solutions are not only environmentally sustainable but also socially impactful, meeting the diverse needs of local populations[14].

Decentralized solar systems also promote economic empowerment by creating local jobs and enabling community ownership of energy resources. Unlike centralized models that often concentrate economic benefits in urban or industrial centers, decentralized systems distribute these benefits more equitably. Jobs in installation, maintenance, and management of solar projects provide opportunities for skill development and income generation. Furthermore, when communities have direct control over energy production, they can reinvest the economic gains into local development, fostering long-term sustainability and cohesion[15].

By integrating social equity into climate solutions, decentralized solar systems are uniquely positioned to address the Euromed region's intertwined challenges. Vulnerable populations, who are often the most affected by climate change, can actively participate in and benefit from the renewable energy transition. This approach not only accelerates the shift to clean energy but also bridges development gaps between urban and rural areas, creating a more equitable and resilient energy future.

This research delves into the potential of decentralized solar systems to scale as a regional strategy for sustainable and inclusive growth. By exploring models of implementation, financing mechanisms, and policy frameworks, the study aims to highlight pathways for maximizing their impact. In doing so, it aligns with broader goals of the European Green Deal and the United Nations Sustainable Development Goals, which emphasize the need for integrated solutions to global climate and equity challenges.

Research Objectives and Key Questions

The primary objective of this research is to explore how decentralized solar energy systems can serve as catalysts for social and territorial equity in the Euromed region, addressing the intertwined challenges of climate action and socio-economic disparity. By focusing on the role of renewable energy systems in underserved communities, the study aims to uncover pathways through which decentralized solar initiatives can empower populations, reduce energy poverty, and foster regional resilience.

At the heart of this research are several guiding questions that address the critical dimensions of decentralized solar energy systems and their potential impact. The first question examines how these systems improve energy access and alleviate energy poverty in marginalized communities. This includes

[14] National Institutes of Health, Harnessing Africa's untapped solar energy potential for health - PMC, 2014.

[15] World Economic Forum, How solar energy is becoming a game-changer in the fight against climate change, 2023.

evaluating their effectiveness in areas with limited or no connection to centralized grid infrastructures and determining how such systems enhance the quality of life for vulnerable populations.

A second key inquiry delves into the socio-economic benefits of decentralized solar systems, including their capacity to create jobs, generate local income, and strengthen community resilience. By analyzing specific case studies, the research will assess the extent to which these systems contribute to sustainable economic development and reduce disparities between urban and rural areas. The investigation will also explore how decentralized energy models influence community cohesion and participation.

Another central focus of the study is the impact of community ownership and management models on social and territorial equity. This question seeks to understand whether these participatory frameworks lead to a fairer distribution of resources and benefits compared to centralized or privately-owned energy structures. The research will assess the implications of giving communities direct control over energy production and revenue allocation and its role in fostering inclusive governance.

Finally, the research addresses the policy and regulatory landscape necessary to scale decentralized solar systems effectively in the Euromed region. It will identify existing barriers within current frameworks, such as funding gaps, regulatory restrictions, or market dynamics that inhibit adoption. The study will propose policy reforms and strategies to encourage widespread deployment of decentralized systems while ensuring that social equity remains a priority. Particular attention will be paid to aligning recommendations with regional and global initiatives, including the European Green Deal and the United Nations 2030 Agenda.

Through these guiding questions, the research aims to provide actionable insights for policymakers, energy planners, and community organizations. By doing so, it contributes to building a more inclusive, sustainable, and climate-resilient energy future for the Euromed region, demonstrating how decentralized solar energy systems can play a pivotal role in addressing the dual imperatives of climate action and social justice.

LITERATURE REVIEW

The body of research on decentralized renewable energy (DRE) emphasizes its transformative role in advancing sustainability, energy access, and resilience, especially in regions with limited or unreliable energy infrastructure. DRE systems, particularly decentralized solar energy, are increasingly recognized as essential tools for achieving climate action and social equity, especially in geographies like the Euromed region, where diverse socio-economic and environmental conditions demand adaptable solutions.

Solar Energy Potential in the Euromed Region

The Euromed region holds significant potential for solar energy development, driven by its high solar irradiance levels, which are among the highest globally. Studies emphasize that this renewable energy resource is both technically feasible and economically viable for meeting energy needs across North Africa, Southern Europe, and the Middle East. Decentralized solar energy systems—such as rooftop panels, microgrids, and small-scale solar farms—are particularly effective for regions where extending the centralized grid is either logistically challenging or cost-prohibitive[16].

Research indicates that these systems can significantly improve energy access in rural and remote areas, addressing energy poverty while also supporting sustainable development. For example, in Southern Mediterranean countries like Morocco and Tunisia, solar initiatives are being scaled to meet national and regional energy needs while fostering socio-economic development[17]. The European Union is actively promoting cooperation to harness solar energy as a key part of climate and energy strategies[18]. From an economic perspective, decentralized solar installations are also cost-effective. Their availability and affordability, supported by favorable regulations, makes solar energy an attractive investment in the Euromed region[19].

Community Empowerment and Social Equity

Community empowerment through decentralized renewable energy systems, particularly solar energy, is a growing focus in sustainability research. These systems are celebrated for their ability to align environmental goals with socio-economic development, especially in regions that face energy poverty and significant socio-economic disparities. Decentralized models such as community solar farms and microgrids provide

[16] Lugo-Laguna D, Arcos-Vargas A, Nuñez-Hernandez F. A European Assessment of the Solar Energy Cost: Key Factors and Optimal Technology. Sustainability. 2021; 13(6):3238. https://doi.org/10.3390/su13063238

[17] Le Monde, Solaire : au Maghreb, des centaines de jours de soleil mais un gros retard à rattraper, 2022.

[18] IEMed, Renewable Energy in the Euro-Mediterranean Framework, 2021.

[19] European Commission, The Untapped Area Potential for Photovoltaic Power in the European Union, 2020.

opportunities for marginalized groups to gain control over their energy resources. By involving communities directly in planning, ownership, and management, these initiatives foster a sense of agency and collective responsibility. This participatory approach also enhances social cohesion, builds trust among stakeholders, and strengthens local governance structures[20].

One of the most tangible benefits of decentralized renewable energy projects is job creation. These projects generate employment opportunities in installation, operations, and maintenance, driving economic growth at the local level. For instance, vocational training programs tailored to renewable energy have been successful in equipping rural populations with the skills needed to sustain these systems. Furthermore, women and underrepresented groups often benefit significantly, with projects designed to integrate a gender-inclusive perspective contributing to broader economic empowerment[21].

The International Renewable Energy Agency (IRENA) emphasizes the importance of an ecosystems approach to renewable energy development[22]. This strategy involves not just deploying technology but ensuring the infrastructure integrates with local livelihoods. It includes capacity building, policy support, financing tailored to community needs, and promoting innovation. For example, results-based financing models and cooperatives in India have successfully supported farmers by reducing upfront costs for renewable energy adoption, enhancing productivity while driving sustainability. These initiatives illustrate how renewable energy can serve as a tool for both economic empowerment and environmental stewardship.

Decentralized systems also play a crucial role in addressing territorial and social inequities by delivering reliable, affordable energy to underserved regions. In remote areas where centralized grids are financially and logistically challenging to extend, decentralized solar installations provide an immediate and effective solution to provide electricity. This not only reduces reliance on expensive, polluting energy sources but also improves the quality of life for rural populations. By bridging the energy access gap, these projects mitigate the risk of energy poverty and ensure equitable distribution of the benefits of renewable energy transitions[23].

Addressing Spatial Inequalities Through Decentralized Renewable Energy

Decentralized renewable energy (DRE), particularly solar energy systems, has significant potential to address spatial and territorial disparities in the Euromed region. Many peripheral and underserved areas in Africa experience chronic energy poverty and economic marginalization. For instance, in sub-Saharan Africa, only 31% of rural areas have access to electricity, leaving a significant portion of the population without reliable energy[24]. These regions often lack the infrastructure required for centralized energy systems, making decentralized solutions a practical and transformative approach. By providing localized energy access,

[20] Coy, D, Malekpour, S, Saeri, AK & Dargaville, R. Rethinking community empowerment in the energy transformation: A critical review of the definitions, drivers and outcomes, Energy Research & Social Science, 2021.

[21] International Renewable Energy Agency (IRENA), Renewable energy: A gender perspective, 2019.

[22] Ibid.

[23] International Renewable Energy Agency (IRENA), Fostering Livelihoods with Decentralised Renewable Energy: An Ecosystems Approach, 2022.

[24] Jeune Afrique, L'électrification rurale décentralisée : une réponse à la pauvreté énergétique en Afrique, 2023.

DRE initiatives enable these communities to achieve energy independence, reducing their vulnerability to fluctuating global energy prices and enhancing their resilience to environmental and economic challenges[25].

DRE systems play a vital role in fostering regional development by improving access to reliable and affordable energy. This access is critical for enhancing rural living standards, reducing migration pressures to urban centers, and promoting balanced territorial development. Improved energy access supports economic activities in agriculture, small-scale manufacturing, and services, creating employment opportunities that help stabilize local economies. For instance, initiatives in sub-Saharan Africa and parts of Asia have demonstrated the potential of community solar systems to drive rural development by powering essential services like water pumping, refrigeration for medical supplies, and educational facilities[26].

The literature further emphasizes that DRE projects can bolster social and territorial cohesion. By targeting historically neglected regions, these systems help to bridge the gap between urban and rural areas, enabling equitable development. IRENA highlights the role of renewable energy in reducing spatial inequalities by fostering local enterprise development and ensuring that energy access is inclusive. Tailored financial incentives and participatory models also contribute to the success of DRE projects, as seen in case studies from India, where renewable energy systems have revitalized rural economies by creating local value chains[27].

Policy frameworks that prioritize spatial equity are crucial for scaling these benefits. Governments and international organizations can invest in capacity-building initiatives, foster inclusive public-private partnerships, and implement regulatory reforms that support decentralized energy deployment in marginalized regions. The successful implementation of decentralized solar energy projects can mitigate spatial disparities in energy access. For instance, decentralized renewable energy systems have been effectively deployed to enhance local livelihoods in various regions such as the EU, the MENA region, and the broader Euro-Mediterranean area. Tailored energy solutions, financing, capacity building, market access, and policy support contributes to address the challenges faced by underserved communities[28]. These findings underscore the transformative potential of DRE systems as tools for advancing both regional equity and sustainable development.

Challenges and Constraints

Despite the significant potential of decentralized renewable energy (DRE) systems in the Euromed region, several challenges impede their widespread adoption. One of the primary obstacles is financing. The high upfront costs associated with solar installations, such as the purchase and installation of

[25] International Renewable Energy Agency (IRENA), Renewable energy for remote communities: A guidebook for off-grid projects, 2023.

[26] The Guardian, 'Solar Mamas empower our people by giving them electricity': the women lighting up Zanzibar, 2025.

[27] International Renewable Energy Agency (IREA), Decentralised solar PV: A gender perspective, 2024.

[28] International Renewable Energy Agency (IRENA), Fostering Livelihoods with Decentralised Renewable Energy: An Ecosystems Approach, 2022.

equipment, represent a substantial barrier for communities, particularly in rural or economically disadvantaged areas. Access to credit is often limited, and many small-scale developers lack the financial resources to fund such projects independently. The International Renewable Energy Agency (IRENA) highlights that innovative financial mechanisms, such as microfinancing or public-private partnerships, are crucial for overcoming this challenge[29]. However, these financial solutions are not yet widespread, and many regions still struggle to secure the necessary investment for decentralized systems.

In addition to financing, regulatory and policy barriers present significant constraints. Many Euromed countries have energy policies that favor centralized energy systems, with limited provisions for small-scale or decentralized solar installations[30]. Existing regulations often do not provide the necessary incentives or clear pathways for integrating decentralized energy solutions into national grids. As a result, communities that could benefit the most from these systems face delays and additional hurdles in implementing projects. Moreover, the lack of alignment between local energy policies and renewable energy goals hampers the scalability of decentralized solar energy projects in the region. IRENA and various international organizations have called for more inclusive and forward-thinking energy policies to foster the growth of decentralized systems.

Further compounding these challenges are capacity deficits, both technical and institutional. In many underserved regions, the lack of skilled labor for installation and maintenance, as well as insufficient institutional capacity to manage and monitor these systems, poses a significant risk to the long-term sustainability of DRE projects. Without robust local capacity-building programs, these systems may fail to function optimally over time, leading to inefficiencies and potential breakdowns. Additionally, many local institutions lack the expertise to oversee the operation and maintenance of DRE systems, which are often more complex than conventional energy solutions[31].

To overcome these challenges, research suggests the need for comprehensive strategies that combine financial, regulatory, and capacity-building initiatives. These strategies should aim to create supportive policy frameworks, establish better financing options for small-scale energy solutions, and invest in local skills development to ensure the longevity and success of decentralized solar projects.

Research Gaps and Opportunities

While existing literature has provided a substantial understanding of the benefits and challenges of decentralized renewable energy (DRE) systems in the Euromed region, notable gaps remain that could further enhance the field's development. A significant area lacking in-depth analysis is the specific dynamics of community ownership models within the context of the Euromed region. Although there is a growing body of literature on the benefits of community-led renewable energy systems, few studies have explored how these models operate in the diverse socio-political and economic environments of

[29] International Renewable Energy Agency (IRENA), Partnerships, [accessed February 2025].

[30] Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN), Développement des Énergies Solaires au Maroc, 2023.

[31] International Energy Agency, Financing Clean Energy Transitions in Emerging and Developing Economies, 2021,

the Euromed region. This is a crucial gap, as community ownership can play a transformative role in empowering marginalized groups, improving social cohesion, and fostering long-term sustainability. Understanding how local contexts—such as cultural, economic, and institutional factors—shape the success of community-owned energy systems in this region is an area ripe for exploration[32].

Additionally, there is a lack of research into the long-term socio-economic impacts of decentralized solar energy projects on marginalized populations. While many studies highlight the immediate benefits of decentralized solar systems, such as improved energy access and job creation, few have examined their broader and more lasting socio-economic effects. This includes the impacts on local economies, education, and public health in communities that are often excluded from mainstream economic activities. Long-term studies are needed to assess how these systems contribute to reducing poverty, enhancing local economic development, and improving social equity over time[33].

Another significant gap is the research on the policy innovations needed to harmonize national energy strategies with the unique needs of peripheral and marginalized communities. Although various studies have focused on the benefits of decentralized systems, there is limited research on the specific policy and regulatory frameworks that can facilitate their growth in the Euromed region. The current regulatory landscape often favors centralized utilities and presents challenges for small-scale, community-based projects. Research into how policies can be restructured to support decentralized solar systems—such as offering fiscal incentives, adjusting grid integration rules, and creating supportive legal frameworks—represents an important opportunity for future exploration[34].

To address these gaps, further research is needed on innovative governance models, financing mechanisms, and policy frameworks that can maximize the impact of decentralized solar energy systems. This research should explore how financial tools such as microfinancing, public-private partnerships, and green bonds can be adapted to suit the specific needs of the Euromed region. Additionally, studies should focus on the design and implementation of policies that ensure the equitable distribution of energy benefits, promote local ownership, and support the long-term sustainability of decentralized systems. By focusing on these areas, future research can provide the insights needed to unlock the full potential of decentralized solar energy in tackling the region's environmental and socio-economic challenges.

[32] Research Center for Sustainability, Freie Universität Berlin, Implementing European Union Provisions and Enabling Frameworks for Renewable Energy Communities in Nine Countries: Progress, Delays, and Gaps, 2023.

[33] Eric Sippert, Environmental Law & Policy Center, Community-Owned Community Solar: Opportunities and Challenges, 2021-2022.

[34] Energy, Sustainability and Society, Perceptions of participation and the role of gender for the engagement in solar energy communities in Sweden, 2021.

RESEARCH METHODOLOGY

CASE STUDIES AND POLICY ANALYSIS

This section outlines the methodology employed in the research, which combined in-depth case studies and policy analysis to explore decentralized solar energy projects in the Euromed region. The approach aimed to examine both the practical outcomes of existing initiatives and the regulatory frameworks that influence their success and scalability.

The research primarily focused on case studies of successful decentralized solar energy projects in the Euromed region. By examining existing projects, the research sought to understand their socio-economic impacts, including their effects on community empowerment, job creation, and energy access. These case studies provided insights into the governance models employed, the barriers faced during implementation, and the strategies used to overcome these challenges. The findings offered valuable lessons and best practices that could be applied to similar projects in other regions.

The research also included a policy analysis to assess the current regulatory frameworks surrounding decentralized solar energy. This involved a comparative review of the policies in different Euromed countries to identify factors that either promoted or hindered the adoption of decentralized solar systems. The policy analysis highlighted areas where reforms were needed to foster the growth of decentralized energy initiatives, ensuring that national energy strategies aligned with the unique socio-economic needs of marginalized communities.

Rationale for Selecting Case Studies and Data Sources

The selection of case studies for this research is a critical component in understanding the impact of decentralized solar energy systems across diverse contexts in the Euromed region. The diversity of the region, which includes Southern Europe, North Africa, and the Middle East, offered a rich variety of socio-economic conditions and regulatory environments, making it crucial to capture how decentralized solar systems functioned under different local circumstances. Each sub-region presented unique challenges and opportunities, including varying levels of solar irradiance, access to infrastructure, and economic development. By selecting case studies across these areas, the research aimed to provide a comprehensive picture of how decentralized solar energy systems could be tailored to meet the specific energy needs of different communities. The research therefore explored regions where these systems had been implemented, focusing on both urban and rural areas, and highlighted the particular impacts on marginalized communities that were underserved by traditional energy infrastructures.

The scale and scope of the selected projects were also key factors in ensuring a thorough understanding of decentralized solar systems. A mix of small-scale, community-owned projects and larger, regional solar initiatives allowed for the comparison of different models of ownership and governance. Small-scale projects often involved localized ownership and management, which could lead to more direct and tangible benefits for communities, including increased energy independence and empowerment. Larger, regionally coordinated projects, on the other hand, offered economies of scale and facilitated wider community involvement, allowing for lessons to be learned about scaling decentralized energy systems across broader geographic areas.

Comparing these different scales of operation provided insights into the trade-offs between local control and broader regional coordination and how each model influenced social, economic, and environmental outcomes. Additionally, examining these diverse projects shed light on the role of community engagement in the success of decentralized solar systems. Projects that actively involved local populations in the planning, ownership, and management of solar systems were believed to foster stronger community ties and increase the sustainability of energy solutions. The research prioritized case studies where participatory planning and local ownership were central to the design of the project, as these elements likely had a significant impact on social equity and community empowerment.

The socio-economic contexts of the selected case studies also varied, with a focus on rural areas, urban areas, and communities that were off-grid or underserved by national energy networks. These marginalized communities often faced significant energy poverty, lack of infrastructure, and limited access to affordable energy. By including case studies in these contexts, the research examined how decentralized solar systems provided energy access and reduced dependence on external sources. In these areas, decentralized solar systems had the potential to stimulate local economic development by creating jobs, improving living standards, and reducing migration pressures to urban centers. By focusing on communities that had been historically underserved, the research explored how decentralized solar energy contributed to regional development, fostered territorial cohesion, and addressed spatial inequalities. In these contexts, decentralized solar systems served as both a tool for energy independence and a catalyst for broader socio-economic transformation.

Project documentation, including reports on the design, implementation, and outcomes of decentralized solar systems, was essential for understanding how these projects functioned and their socio-economic impacts. These documents provided valuable technical and financial data, as well as insights into the challenges faced by project developers and communities. Policy reports and government publications provided context on the regulatory frameworks that shaped the development of decentralized solar energy in different countries. These documents allowed the research to assess how national and regional policies influenced the success of decentralized solar systems, particularly in terms of financing, regulation, and incentives. Lastly, data from international organizations, such as the International Renewable Energy Agency (IRENA) and the World Bank, were used to track the broader trends in decentralized renewable energy development in the Euromed region. These sources helped to contextualize the case studies within the larger global shift towards sustainable energy systems, offering comparative insights and best practices.

By drawing on these diverse data sources, the research provides an understanding of the potential for decentralized solar energy systems to contribute to social equity, economic development, and territorial cohesion in the Euromed region. The combination of geographic, socio-economic, and project-specific diversity ensured that the case studies offered valuable lessons for policymakers and energy practitioners seeking to promote sustainable and inclusive energy solutions across the region.

Data Collection and Analysis Procedures

Policy documents, legislative texts, and regulatory guidelines related to renewable energy and decentralized energy systems were collected from a variety of national and regional government sources. These documents are crucial for understanding the legal and regulatory frameworks that influenced decentralized solar systems. They provided the necessary background on energy policies, laws regarding grid integration, and renewable energy incentives that could either promote or impede the adoption of solar energy projects. Additionally, they offered insights into the institutional and financial mechanisms available to support such initiatives, as well as the challenges posed by existing legal barriers. This collection of policy documents helped identify key trends and gaps in current frameworks that impact the widespread implementation of decentralized solar energy solutions.

Policy Analysis provided a comparative review of the regulatory frameworks governing renewable energy in the Euromed region. This analysis examined policies that supported or hindered the adoption of decentralized solar systems, focusing on key factors such as subsidies, incentives, permitting processes, and support for community ownership. By comparing the policy environments across various countries, this component identified successful models that could be scaled up and implemented in other regions, as well as gaps or barriers that needed to be addressed. Additionally, the policy analysis reviewed barriers to adoption, such as regulatory restrictions or insufficient support for community-driven projects, and suggested policy reforms to enhance the scalability and equity of decentralized solar initiatives.

CASE STUDIES

This research explores several in-depth case studies of successful decentralized solar energy projects within the Euromed region, highlighting a variety of project scales, community engagement models, and regional contexts. These cases represent the diverse socio-economic, geographical, and political landscapes of southern Europe, North Africa, and parts of the Middle East. Through these case studies, the study aims to illustrate both the potential benefits and challenges of decentralized solar initiatives across different settings.

CASE STUDY 1: COMMUNITY-OWNED SOLAR PROJECT IN RURAL SPAIN

One notable example of a successful decentralized solar project is the Crevillent Local Energy Community[35], located in a rural area of southern Spain. Developed by the Enercoop cooperative, this initiative addresses both energy access and economic challenges by enabling local residents to collectively invest in and manage renewable energy infrastructure. Through a cooperative model, community members pooled resources to install solar panels on residential and public buildings, including schools and healthcare centers, ensuring a stable and affordable energy supply.

The cooperative structure has been fundamental to the project's success, allowing residents to maintain control over energy production and management. This local ownership model has ensured the long-term sustainability of the initiative, fostering both financial investment and active participation in system maintenance and operation. Additionally, the project has led to significant socio-economic benefits for the village. Household energy costs have decreased, generating financial savings, while the initiative has also created local green jobs, supporting economic stability. The collaborative nature of the project has strengthened social cohesion, as residents work together towards shared sustainability goals.

The case of Crevillent highlights the transformative potential of decentralized solar energy, offering not only technical solutions for energy access but also broader social and economic advantages. By reducing energy poverty and enhancing community resilience, this model serves as an example for other rural communities in Spain and beyond, demonstrating how renewable energy can drive local empowerment.

[35] One Earth, Crevillent – Spain's first local energy community | One Earth, 2021.

Box 1: Cost of Building a Decentralized Solar Power Installation in Spain[36]

The cost of building decentralized solar power installations in Spain varies based on system size, location, and technology. As of 2024, the average cost of solar panels in Spain ranges between €1,000 and €2,500 per installed kilowatt (kW). This means that for a typical 5 kW residential system, total costs can range from €5,000 to €12,500, before applying any government incentives or subsidies.

Breaking down these costs, solar panels themselves account for approximately €600 to €1,200 per kW, while the inverter, a crucial component for converting solar energy into usable electricity, typically costs between €1,000 and €2,000, depending on system capacity. Installation expenses, which include labor and mounting structures, can range from €1,000 to €3,000, depending on complexity and location. Additionally, permits, inspections, and miscellaneous administrative fees can add an extra €500 to €1,000 to the total cost.
Despite these initial investment requirements, decreasing solar technology costs, coupled with Spain's government incentives and net metering schemes, have made decentralized solar energy increasingly accessible. These financial trends are particularly beneficial for rural areas, where decentralized solar systems provide an economically viable and sustainable alternative to traditional grid expansion.

Box 2: Job Creation and Workforce Training in the Solar Sector[37]

The solar energy sector in Spain has emerged as a major driver of job creation, with a steadily increasing demand for skilled professionals across various levels of expertise. In 2022, the renewable energy sector in Spain accounted for a total of 130,815 direct and indirect jobs, with the photovoltaic industry experiencing the most significant growth. The country's National Integrated Energy and Climate Plan (PNIEC) 2021-2030 forecasts the creation of thousands of additional jobs, as Spain aims to install 76 gigawatts (GW) of photovoltaic capacity by 2030.

One of the key contributors to employment growth in the solar sector is the increasing investment in decentralized solar systems, particularly for self-consumption and community solar projects. The expansion of rooftop solar installations and solar cooperatives has created new opportunities for local businesses and independent solar professionals, including system designers, electricians, and maintenance technicians.

However, despite the strong employment prospects, the sector faces a skills gap, with a shortage of qualified workers trained in solar photovoltaic installation, energy storage, and grid integration. To address this challenge, Spain has expanded vocational training programs, particularly through public-private

[36] Evergreen Electrica, How Much Are Solar Panels in Spain? Pricing and Insights.

[37] SEPE - Servicio Público de Empleo Estatal, Employment in the renewable energy sector in Spain: situation and trends, 2023.

partnerships. The Spanish Institute for Energy Diversification and Saving (IDAE) and various regional governments have introduced specialized courses in renewable energy technologies, enabling workers to acquire the necessary certifications.

Additionally, large companies have started collaborating with universities and vocational training centers to offer internships and apprenticeships, helping students gain hands-on experience in solar energy projects. However, a significant challenge remains in ensuring that training programs are aligned with the evolving needs of the industry, particularly as battery storage, smart grids, and digital energy management become more integral to solar systems.

Overall, the Spanish solar energy sector is poised to continue generating substantial employment opportunities, provided that ongoing investments in workforce training and education keep pace with the industry's rapid expansion. By addressing existing labor shortages and enhancing technical training, Spain can further solidify its position as a European leader in the renewable energy transition.

CASE STUDY 2: DECENTRALIZED SOLAR SELF-PRODUCTION IN TUNISIA

A successful example of decentralized solar self-production in Tunisia demonstrates how such systems can enhance energy access and sustainability for households. Under this regime, which has been in place since 2009 and reinforced by the 2015 regulatory framework, low-voltage consumers can install photovoltaic (PV) systems to generate their own electricity while remaining connected to the national grid. This model has been widely adopted through Prosol Elec[38], a program launched in 2010 that integrates an innovative financing mechanism involving STEG, ANME, certified solar providers, and partner banks, making solar energy more accessible to households across the country. By the end of 2022, nearly 160MW of decentralized solar capacity had been installed, significantly reducing reliance on conventional electricity sources.

The program has been supported through national and international partnerships and partially financed via government-backed subsidies and loans. It has not only improved access to clean energy but also placed strong emphasis on capacity building. Local technicians have been trained to install and maintain PV systems, creating jobs and fostering the development of the solar energy sector. Additionally, recent advancements in energy storage solutions have helped address the intermittency of solar power, ensuring that households can maximize the benefits of self-production by using stored energy during low-sunlight periods.

This decentralized solar model serves as a key example of how self-production systems can support Tunisia's energy transition. Its success lies in its ability to combine clean energy generation, cost savings

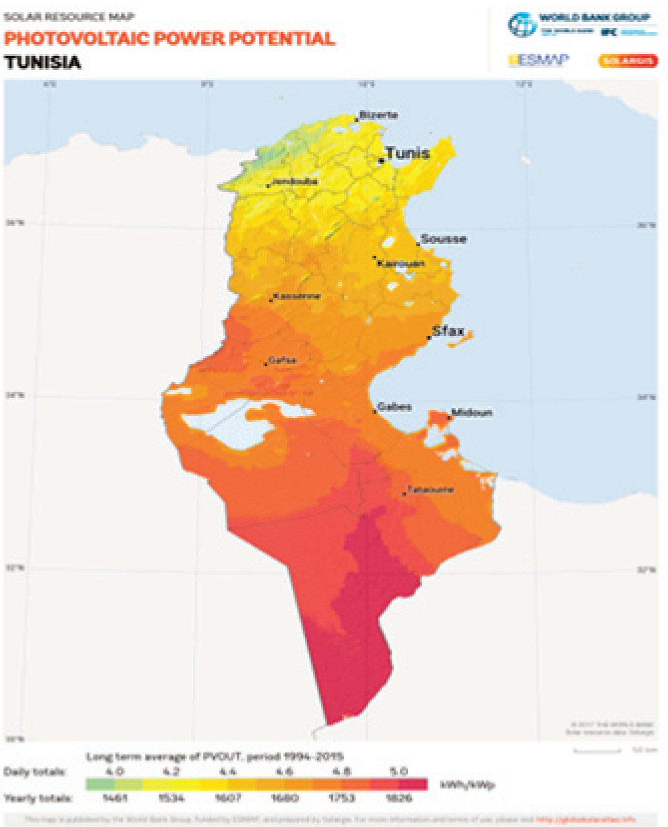
[38] Ministère de l'Energie, des Mines et des Énergies renouvelables : Régime de l'autoproduction. Tunisie. 15/12/2025.

for consumers, job creation, and reduced dependence on fossil fuel imports, aligning with Tunisia's national goal of increasing renewable energy adoption and strengthening energy independence[39].

Photovoltaic Power Potential in Tunisia

Tunisia has significant photovoltaic (PV) power potential, particularly in regions like El Akarit, Gabes, which receive high levels of solar irradiation. A study using deep learning algorithms to analyze historical climate data from NASA and the Tunisian National Institute of Meteorology suggests that PV production in Tunisia is expected to increase despite climate change[40]. The study highlights the importance of site selection, considering factors such as solar resource availability, proximity to transmission lines, and land suitability. While conventional radiation measurement methods can be costly and limited in scope, AI-based predictions provide a cost-effective and accurate tool for assessing Tunisia's long-term solar energy potential. These findings reinforce Tunisia's commitment to renewable energy expansion and energy security, positioning the country as a strong candidate for future PV investments.

Figure 1. Photovoltaic Power Potential in Tunisia[41]



[39] World Bank, Green Energy Production in Tunisia: The World Bank Group Assistance, 2024.

[40] Othman, A. B., Ouni, A., and Besbes, M., Deep learning-based estimation of PV power plant potential under climate change: a case study of El Akarit, Tunisia, 2020.

[41] Ibid.

Box 3: Cost of Building a Decentralized Solar Power Installation in Tunisia[42]

Approximately 70% of approved photovoltaic projects in medium voltage in Tunisia have an average cost below 3,500 TND per kilowatt (kW) installed. With the current exchange rate of 1 TND = 0.3135 USD, this equates to approximately $1,097 per kW. Therefore, a 3 kW installation would cost around 10,500 TND, or approximately $3,290. It is important to note that these costs can vary depending on several factors, including equipment quality, labor costs, and specific site conditions. For a more accurate estimate tailored to individual needs, it is recommended to consult recent studies or local solar energy experts.

Job Creation and Workforce Training in the Tunisian Solar Sector

The expansion of decentralized solar power in Tunisia presents a major opportunity for job creation across various sectors including installation maintenance and system operation. According to a 2015 study[43], approximately 2874 direct jobs had been generated through renewable energy (RE) and energy efficiency (EE) programs with 67 percent of these jobs concentrated in the residential solar sector. The Solar Program (PROSOL) has been instrumental in promoting solar thermal and photovoltaic (PV) technologies. Projections under the Energy Efficiency and Renewable Energy (EE&ER) scenario[44] indicate that more than 25 000 additional jobs could be created by 2030 as the country continues its transition towards sustainable energy sources. Job creation in the solar sector is particularly significant in the supply chain where for each megawatt (MW) of installed solar PV capacity around 40 local jobs are generated for supply and installation, 14 jobs per MW to manufacturing and 8 jobs per MW to system maintenance and operation. These figures highlight the growing demand for skilled technicians and engineers capable of supporting the expansion of solar infrastructure, emphasizing the need for enhanced vocational training programs and technical education initiatives by equipping local workers with the necessary expertise.

Decentralized Solar vs. Centralized Grid Expansion

In Tunisia, decentralized solar power systems have emerged as a more cost-effective and practical solution for rural electrification compared to centralized grid expansion[45]. The cost of solar energy production has declined significantly, ranging between 0.10 and 0.15 USD/kWh, making it competitive with conventional grid electricity. In contrast, extending the national grid to remote or off-grid communities entails substantial infrastructure investments, with costs reaching between 5,000 and 10,000 USD per household. These high expenses make centralized grid expansion financially burdensome, particularly in sparsely populated or geographically challenging areas[46].

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[42] Noura Laroussi Ben Lazreg, Les énergies renouvelables en Tunisie, 2020.

[43] GIZ. Énergie renouvelable et efficacité énergétique en Tunisie : emploi, qualification et effets économiques: Nouveaux cadres -Nouveaux résultats, 2016.

[44] ANME (2014) *Stratégie de Développement de l'Efficacité Énergétique et des Énergies Renouvelables à l'Horizon 2030 (Scénario EE&ER)*. Tunis: Agence Nationale pour la Maîtrise de l'Énergie.

[45] International Renewable Energy Agency (IRENA), Évaluation de l'état de préparation aux énergies renouvelables : République tunisienne, 2021.

Decentralized solar microgrids, on the other hand, offer a more affordable and flexible alternative, enabling quicker deployment and tailored energy solutions that meet local needs. Unlike centralized grids, which depend heavily on fossil fuel imports, decentralized solar systems enhance energy security by reducing reliance on external energy sources. Additionally, they mitigate the risks associated with power outages and fluctuating energy prices, ensuring a more stable and resilient energy supply. Given these advantages, decentralized solar solutions present a sustainable and economically viable path for expanding electricity access in rural Tunisia, aligning with the country's broader energy transition goals.

Socio-Economic Impact: Standard of Living and Local Unemployment Rates

Decentralized solar projects in Tunisia have a positive socio-economic impact by improving the standard of living and reducing local unemployment rates. Lower energy costs increase household disposable income, leading to better access to essential services such as education and healthcare. Furthermore, decentralized solar initiatives stimulate local economies by creating stable employment opportunities in installation, maintenance, and system management. By empowering local communities through ownership and governance models, these projects also foster economic independence and social cohesion[47].

CASE STUDY 3: SOLAR-POWERED AGRICULTURAL COOPERATIVE IN MOROCCO

In Morocco's Souss-Massa region, the implementation of a solar-powered energy system by a local agricultural cooperative serves as a compelling example of the transformative impact of decentralized renewable energy on rural agricultural practices. The cooperative installed a solar energy setup to power irrigation systems and other agricultural equipment, replacing the traditional reliance on expensive and polluting diesel generators[48]. This shift significantly reduced operational costs, lowered the environmental impact, and improved the cooperative's ability to cultivate crops throughout the year, addressing challenges posed by the region's semi-arid climate[49].

The system's success can be attributed to several key factors. First, it received strong support from Morocco's progressive agricultural policies, particularly under the Green Morocco Plan (Plan Maroc Vert), which emphasizes sustainable resource use and energy efficiency in farming. This policy framework facilitated access to financial support and technical expertise, enabling the cooperative to design and deploy a reliable solar energy system tailored to its needs. Moreover, the initiative aligns with Morocco's broader renewable energy strategy, which aims to increase the share of renewables in the country's energy mix and improve rural electrification rates[50].

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[46] Ibid.

[47] Lehr, U., Mönnig, A., Missaoui, R., and Marrouki, S., Énergie renouvelable et efficacité énergétique en Tunisie : emploi, qualification et effets économiques, 2012.

[48] Climate Change Observatory team, Satisfying New Renewable Energy Demands, Souss-Massa, Global Observatory on Non-state Climate Action, 2019.

[49] High Atlas Foundation, Harnessing the Sun: Capitalizing on Morocco's Most Abundant Resource to Power Transformative Solar-Powered Irrigation Systems, 2021,

[50] International Finance Corporation, IFC Guarantees Loan to Provide Farmers, Agribusiness SMEs in Morocco with Solar and Efficient Irrigation

Economically, the project generated significant benefits for the cooperative and its members. The reduction in energy costs translated directly into increased profitability, allowing the cooperative to reinvest in infrastructure and expand its activities. This improvement also helped stabilize agricultural production, enhancing food security and supporting local livelihoods. Additionally, the cooperative members gained new skills related to the operation and maintenance of solar systems, fostering capacity building and self-reliance within the community[51].

Environmentally, the transition from diesel to solar energy dramatically reduced greenhouse gas emissions associated with agricultural activities. This has strengthened the cooperative's resilience against fluctuating fuel prices and aligns with global efforts to mitigate climate change. The project's sustainability and scalability have drawn attention as a model for similar rural and agricultural settings in Morocco and beyond.

The Souss-Massa solar initiative underscores how decentralized solar energy can address interlinked socio-economic and environmental challenges in rural areas[52]. By combining renewable energy with targeted agricultural development policies, the project demonstrates a pathway for achieving sustainable development goals, including poverty reduction, clean energy access, and environmental sustainability.

Cost of Implementing Solar-Powered Agricultural Systems in Morocco

The implementation of solar-powered agricultural systems in Morocco represents a significant investment, with costs varying depending on the scale and financing model. A study[53] identifies different scenarios: a fully self-financed system, a system with a 50/50 capital split, and another with 20% equity and 80% external funding. The cost of investment per kilowatt-peak (kWc) ranges between 26,484 and 38,588 MAD, with operational expenses estimated at 1% of the investment cost annually. The cost of electricity production varies accordingly, reaching 1.06 MAD/kWh for small systems and up to 1.81 MAD/kWh for larger installations when financed primarily through external capital[54].

Decentralized Solar vs. Centralized Grid Expansion

Decentralized solar power presents a cost-effective alternative to centralized grid expansion, especially in rural areas where the cost of extending the national grid can be prohibitively high. The report estimates that grid extension costs can exceed 5,000 to 10,000 USD per household, whereas solar microgrid solutions are more financially viable. Additionally, decentralized solar energy enhances energy security

Systems, 2023.

[51] Asian Journal of Agriculture and Food Sciences, The Economic and Environmental Benefits of Solar Energy in the Agricultural Sector: The Case of Morocco, 2020.

[52] Association Climate Change, Souss Massa - Meeting new energy demands through renewables, 2019.

[53] Roberto Ariel Telleria Juárez, Hassane Serghini Idrissi, Ampaitepin Singhabhandhu, Aden Aw-Hassan, Abdelali Laamari, The Economic and Environmental Benefits of Solar Energy in the Agricultural Sector: The Case of Morocco, 2020.

[54] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Étude du potentiel de développement de l'énergie photovoltaïque dans les régions de Meknès-Tafilalet, Oriental et Souss-Massa-Drâa, 2012.

by reducing dependency on imported fuels and mitigating the risks associated with power outages. The decreasing costs of solar technology further strengthen its competitiveness, with production costs projected to decline to 0.50-0.68 MAD/kWh by 2020[55].

Community Ownership and Local Participation

Community participation is crucial for the successful implementation of decentralized solar projects in Morocco. The study highlights that a significant barrier to solar adoption is the high initial investment cost for households. To address this, policies promoting community-based solar projects, such as financial incentives, simplified administrative procedures, and cooperative ownership models, can encourage local engagement. By fostering local involvement, these initiatives ensure that the benefits of solar energy, including cost savings and energy independence, are equitably distributed across different communities[56].

Socio-Economic Impact: Lower Energy Costs and Job Creation

The expansion of photovoltaic (PV) systems in Morocco has the potential to generate substantial socio-economic benefits. Households that install rooftop solar panels can achieve significant electricity bill savings, with estimated reductions of up to 4,428 MAD per year. Additionally, as solar energy adoption increases, so does job creation. The study projects that by 2030, around 300,000 jobs could be created in the solar energy sector, including positions in installation, maintenance, and manufacturing. This employment growth is expected to contribute to economic development, particularly in regions with high solar potential[57].

Strengthening Community Resilience and Social Cohesion[58]

The expansion of decentralized solar energy in Morocco contributes significantly to strengthening community resilience and social cohesion. By promoting self-sufficiency in electricity production, solar energy reduces reliance on external power sources, ensuring greater stability in remote and underserved communities. Furthermore, the high initial investment costs for photovoltaic installations have been identified as a key barrier to widespread adoption. To overcome this challenge, targeted policies such as financial incentives, reduced administrative barriers, and community-based ownership models can empower local populations to take an active role in energy production.

In addition to energy security, decentralized solar projects foster social cohesion by encouraging local participation in decision-making processes and promoting skills development through training programs. By integrating learning opportunities and business support measures, solar energy initiatives create an ecosystem where communities can benefit not only from lower electricity costs but also from new

[55] *Ibid.*
[56] *Ibid.*
[57] *Ibid*
[58] *Ibid*

employment prospects. This approach ensures that the transition to renewable energy is inclusive and sustainable, reinforcing social ties and economic resilience at the local level.

CASE STUDY 4: URBAN COMMUNITY SOLAR INITIATIVE IN LEBANON

The community solar project in a densely populated neighborhood of Beirut, particularly in areas like Bachoura, exemplifies the potential of decentralized renewable energy systems to address urban energy crises in the Middle East. Lebanon's energy sector is characterized by frequent power outages and a heavy reliance on diesel generators, which are costly and environmentally harmful. This project arose as a local response to these challenges, leveraging public buildings for solar panel installations and distributing the generated electricity to nearby residents.

This initiative was spearheaded in collaboration with local municipalities and supported by community stakeholders[59]. By utilizing public spaces such as schools and municipal buildings, the project minimized infrastructure costs and demonstrated a cost-effective model for solar energy deployment in urban areas. The generated electricity was shared among residents, offering significant financial relief compared to the exorbitant costs of private generators. This was especially impactful in a city like Beirut, where households can pay hundreds of dollars monthly to private generator providers during extended grid outages[60].

Moreover, the project enhanced power reliability, a critical need given the national grid's inability to supply continuous electricity. For residents, the tangible outcomes of reduced bills and a more stable power supply strengthened community support for the initiative. The local government also benefited from reduced energy expenses for public buildings, reinforcing the economic case for decentralized solar systems in urban centers[61].

Despite its success, the project faced several hurdles. Regulatory barriers posed significant delays, as Lebanon's legal framework for renewable energy is still evolving. The absence of streamlined policies for grid integration and renewable energy licensing necessitated creative solutions, such as direct community agreements. Financial constraints were another challenge, addressed partially through crowdfunding and local partnerships[62].

Additionally, the project demonstrated the need for public awareness and education. Community involvement in maintenance and decision-making was pivotal to the initiative's sustainability. Training programs equipped local residents with the technical skills required to maintain the solar infrastructure, fostering a sense of ownership and reducing dependency on external actors.

[59] Lebanese Center for Energy Conservation (LCEC), The 10 Public Buildings Initiative | LCEC, 2017.

[60] AUBPolicy Institute, Beirut as a Smart City: Redefining Urban Energy, 2019.

[61] American Near East Refugee Aid (Anera), Sustainable Energy in Palestine and Lebanon Through Solar Power - Anera, 2022.

[62] Seema Machaca, Radical Urban Lab, Taking Control of the Energy Crisis: Proposing a community owned solar panel system in Beirut, Lebanon, 2024.

This community solar project reflects the broader challenges and opportunities of deploying renewable energy in urban contexts across the region. It aligns with Lebanon's National Renewable Energy Action Plan (NREAP), which sets ambitious goals for solar energy adoption. The project's success serves as a model for scaling similar initiatives, highlighting how decentralized energy systems can simultaneously address urban energy needs and contribute to environmental goals[63].

By demonstrating a viable path for urban renewable energy deployment, the project in Beirut underscores the importance of localized solutions tailored to the socio-economic and regulatory contexts of Middle Eastern cities. It also emphasizes the need for improved policy frameworks, financial incentives, and community engagement strategies to replicate and expand such initiatives.

Cost of Building a Decentralized Solar Power Installation in Lebanon

The cost of constructing a decentralized solar power installation in Lebanon has significantly decreased in recent years due to technological advancements and competitive market conditions. In 2018, the average turnkey price for solar PV installations dropped to $1,195 per kWp, marking a 23% decline from the previous year and an 83% reduction compared to 2011. This decrease surpasses the global average cost drop of 10-15% per year. The lower prices are largely attributed to reduced equipment costs and increased market competition, which has been further driven by local and international tenders. Additionally, the NEEREA financing program and exemptions from customs duties on imported solar panels have contributed to making decentralized solar more affordable for Lebanese businesses and households[64].

Job Creation and Workforce Training in the Solar Sector

The rapid expansion of Lebanon's solar PV sector has led to substantial job creation. The number of solar PV companies in Lebanon increased from just 7 in 2008 to 66 by the end of 2018. As a result, at least 748 jobs have been created within the sector, primarily in installation, maintenance, and engineering roles. This growth is expected to continue, particularly as Lebanon plans to develop its first utility-scale PV farms. Training initiatives and capacity-building programs are essential to ensure a skilled workforce capable of supporting the industry's expansion. Government-backed incentives and partnerships with educational institutions can further enhance workforce readiness and sustain job creation in the renewable energy sector[65].

Comparison of Electrification Costs: Decentralized Solar vs. Centralized Grid Expansion

Decentralized solar energy is emerging as a cost-effective alternative to centralized grid expansion in Lebanon. The total investment in the solar PV sector reached $104.8 million by 2018, with significant

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[63] Arab Reform Initiative, Town Hall Meetings Summary: Lebanon's Solar Energy Boom – Arab Reform Initiative, 2024.

[64] Lebanese Center for Energy Conservation (LCEC), 2018 Solar PV Status Report for Lebanon, 2019.

[65] *Ibid.*

contributions from NEEREA financing. The cost of installing decentralized solar systems continues to decline, with the turnkey price dropping to $1,195 per kWp in 2018. In contrast, extending the centralized grid involves high infrastructure costs and logistical challenges, particularly in remote areas. The increasing cost of diesel for power generation has further incentivized businesses and households to switch to solar PV, as it provides long-term savings and reduces dependency on fluctuating fuel prices. The financial and environmental benefits of decentralized solar make it a viable option for Lebanon's future energy needs[66].

Socio-Economic Impact: Standard of Living and Local Employment Rates

The adoption of decentralized solar PV systems in Lebanon has contributed to an improved standard of living by reducing electricity costs and promoting local employment. By the end of 2018, estimated monetary savings from all solar PV projects reached $4.6 million per year, with cumulative savings totaling $45.4 million. These savings enable households and businesses to allocate resources to other essential needs, thereby improving economic stability. Additionally, the sector has created hundreds of jobs, particularly in regions with high solar adoption, such as Mount Lebanon and Beqaa. As Lebanon moves towards achieving its renewable energy targets, further investments in solar infrastructure will continue to enhance economic resilience, reduce energy insecurity, and create sustainable employment opportunities[67].

CROSS-CASE COMPARATIVE ANALYSIS

The four case studies—Spain, Tunisia, Morocco and Lebanon—highlight a diverse set of conditions and outcomes for decentralized solar energy (DSE) deployment across the Euro-Mediterranean region. Despite significant contextual differences, several common patterns emerge regarding enabling factors, socio-economic impacts and policy challenges.

Enabling Conditions

Across all countries, three key drivers support DSE expansion:

- **High solar resource availability,** which makes decentralized PV systems cost-effective, even in areas with limited grid infrastructure.
- **Falling technology costs,** enabling rapid uptake by households and communities, particularly where retail electricity prices are high or supply is unreliable.
- **Emerging regulatory reforms,** such as Spain's self-consumption framework, Tunisia's PROSOL programme, Morocco's rural electrification plan and Lebanon's crisis-driven adoption of rooftop PV.

However, the strength and consistency of these drivers vary. Spain benefits from mature policies, stable institutions and access to EU funding, whereas Lebanon's growth relies heavily on private initiative in response to systemic grid failure. Tunisia and Morocco sit between these extremes, with structured national programmes but persistent administrative and financial constraints.

[66] *Ibid.*
[67] *Ibid.*

Social Impacts

All four cases show that DSE can significantly reduce household vulnerability to energy insecurity.

- In **Spain**, community energy initiatives have strengthened social cohesion and local participation.
- In **Tunisia,** lower energy bills and new income opportunities contribute to improved living conditions, especially in rural areas.
- In **Morocco**, solar pumping systems enhance water access and support smallholder farmers.
- In **Lebanon**, decentralized solar has become essential for meeting basic needs, greatly improving quality of life amid national electricity shortages.

While social benefits are widespread, the scale and depth of impact depend on affordability and access to financing. Inclusive support mechanisms remain limited in Tunisia and Morocco and largely absent in Lebanon.

Economic Effects

Job creation emerges as a shared positive outcome, though magnitude varies:

- **Spain** shows stable growth in installation, maintenance and cooperative-based employment.
- **Tunisia** demonstrates high job intensity per MW installed, reflecting labour-intensive deployment in residential systems.
- **Morocco** benefits from strong value-chain development but requires further diversification beyond large-scale projects.
- **Lebanon** has seen rapid growth in PV-related employment, albeit in an informal and fragmented market.

Across all cases, DSE lowers energy costs for households and small enterprises, enabling greater economic resilience and local productive uses.

Environmental and Resilience Outcomes

DSE contributes to emissions reduction and improves community resilience:

- **Rooftop and off-grid systems** mitigate reliance on diesel, especially pronounced in Lebanon.
- **Solar pumping** in Morocco reduces fuel use in agriculture.
- **Grid-connected self-consumption** in Spain supports broader decarbonisation targets.
- **Distributed systems** in Tunisia reduce losses and strengthen local energy independence.

Environmental benefits are strongest when supported by policies promoting storage, recycling and circular-economy practices—an area still underdeveloped in all four countries.

Key Barriers

Several common obstacles limit DSE scaling:

- Complex administrative procedures (Spain before reforms; ongoing in Tunisia and Morocco).
- High upfront investment costs, particularly for low-income households.
- Weak institutional capacity and fragmented governance (notably in Lebanon).

- Insufficient support for battery storage, end-of-life recycling and grid integration.
- Limited public awareness and technical training.

Comparative Insight

Spain represents a mature enabling environment, Tunisia and Morocco are intermediate performers with strong potential but structural constraints, while Lebanon illustrates a crisis-driven adoption model where DSE fills systemic governance gaps. This diversity underscores the need for context-specific policies while confirming that DSE consistently enhances social and territorial resilience when supported by appropriate regulatory and financial mechanisms.

SOCIAL, ECONOMIC, AND ENVIRONMENTAL IMPACTS OF DSE

Each of these case studies illustrates significant social, economic, and environmental impacts, highlighting the multifaceted benefits of decentralized solar energy projects.

SOCIAL IMPACTS

Decentralized solar energy projects have demonstrated profound social impacts, as shown by the case studies in Spain, Tunisia, and Morocco. These initiatives transcend the technical provision of energy by fostering community cohesion, empowerment, and resilience, alongside economic and environmental benefits.

Community Empowerment and Engagement

The community-owned solar project in Spain highlights the transformative potential of collective ownership in renewable energy. This initiative fostered a strong sense of solidarity among the residents, who pooled resources to develop and manage the project. Unlike centralized energy systems, where decision-making is removed from local communities, decentralized solar energy encourages active participation. Residents were involved in critical decisions, from site selection to operations, cultivating a shared sense of ownership. This empowered the community to manage its energy needs, reducing reliance on external energy providers. Moreover, the cooperative model demonstrated the viability of grassroots-led energy transitions in rural settings, strengthening trust and mutual responsibility among participants[68].

In Tunisia, the solar microgrid project empowered the local population by integrating them into the renewable energy value chain. Beyond access to reliable electricity, the initiative included skill-building programs that trained residents as solar technicians. This approach not only supported the project's maintenance but also provided sustainable employment opportunities, addressing unemployment challenges in the rural area. These opportunities for skill development have a ripple effect, enabling trained individuals to contribute to other renewable energy projects and fostering a culture of innovation and sustainability.

The agricultural cooperative in Morocco exemplifies how decentralized solar energy can alleviate economic pressures while strengthening community ties. By reducing reliance on expensive diesel generators, the project lowered irrigation costs, directly benefiting farmers. This reduction in economic strain allowed farmers to reinvest in their livelihoods, improving agricultural productivity and ensuring food security. In turn, the cooperative model fostered interdependence and mutual support among

[68] IEA 50, Empowering people – the role of local energy communities in clean energy transitions, 2023.

members, reinforcing a sense of collective responsibility for sustainable farming practices and renewable energy maintenance.

Inclusive Development and Energy Equity

A recurring theme across these cases is the promotion of energy equity. Decentralized solar energy systems address disparities in energy access, particularly in marginalized communities. In Spain, rural residents who were previously vulnerable to energy poverty now have access to affordable and stable energy. In Tunisia, off-grid communities gained a reliable electricity source, bridging the urban-rural divide. These examples show how decentralized solar initiatives can democratize energy, ensuring that historically underserved populations are included in the energy transition[69].

Strengthening Community Resilience

Decentralized energy projects also enhance resilience, especially in the face of climate-related challenges. In all three cases, local communities gained greater control over their energy systems, reducing their exposure to external market fluctuations and political instability. For instance, in Morocco, the transition from diesel to solar energy insulated farmers from the volatility of fuel prices. Similarly, in Tunisia, the hybrid microgrid's battery storage and backup capabilities ensured consistent power during grid failures, crucial for sustaining daily activities and economic productivity[70].

Socio-Cultural Transformation

Beyond economic and technical gains, these projects drive a cultural shift toward sustainability. By embedding renewable energy into local practices, they encourage environmental stewardship and long-term thinking. In Spain, the cooperative model inspired nearby communities to pursue similar initiatives, creating a ripple effect of renewable energy adoption. In Tunisia, the training of local technicians cultivated a new generation of energy advocates who can champion the benefits of solar energy. In Morocco, the cooperative's success serves as a template for integrating renewable energy into agricultural practices, demonstrating the feasibility of sustainable farming powered by clean energy[71].

Broader Implications

These social impacts underscore the transformative potential of decentralized solar energy systems. When combined with participatory models and capacity-building efforts, these projects not only address immediate energy needs but also empower communities to shape their sustainable futures. They offer a replicable blueprint for advancing energy equity, building local capacity, and fostering collective action in regions grappling with energy access challenges.

[69] Climate Portal, Decentralized Renewable Energy for Improving Energy Access in the LDCs, 2019.
[70] MIPA Institute, Enhancing Climate Resilience through Green Energy Transition in Morocco, 2023,
[71] European Investment Bank, Spain renewables projects strengthen Europe energy autonomy, 2023.

ECONOMIC IMPACTS

Decentralized solar energy projects generate significant economic benefits, particularly in underserved and rural areas, as evidenced by the case studies in Morocco, Lebanon, Tunisia, and Spain. These projects address structural energy challenges while fostering local economic development, reducing costs, and enabling financial empowerment for communities. However, the financial viability of such projects is not universal and can be constrained by certain factors, particularly in rural areas with low energy consumption.

Reducing Energy Costs and Increasing Financial Stability[72]

Decentralized solar energy projects have proven to be effective in lowering energy costs and improving financial stability for communities. By replacing expensive diesel generators with solar-powered systems, farmers, businesses, and households have been able to significantly reduce operational expenses. These savings allow reinvestment in productivity-enhancing measures, such as purchasing better seeds and fertilizers in agriculture or expanding businesses that rely on electricity. In urban areas, solar energy solutions provide relief from unreliable and costly central grids, enabling residents to reduce household energy expenses and allocate resources to essential needs. Cooperative solar models further enhance financial stability by allowing members to collectively manage energy production, eliminating intermediaries and ensuring cost efficiency.

Job Creation and Local Economic Growth[73]

Beyond cost reduction, decentralized solar projects generate employment opportunities and stimulate local economies. Training programs for solar technicians equip individuals with the skills needed to install, maintain, and expand renewable energy systems, creating sustainable jobs in growing sectors. The presence of reliable electricity also allows small businesses to operate more efficiently and supports new entrepreneurial ventures, particularly those requiring refrigeration, lighting, or powered machinery. This economic ripple effect extends to households, as reduced reliance on expensive alternatives like diesel generators frees up disposable income, further contributing to economic stability.

Enhancing Energy Security and Reducing Market Vulnerability[74]

One of the most transformative aspects of decentralized solar energy is its role in mitigating economic vulnerabilities associated with fluctuating fuel prices and unreliable electricity grids. In agriculture, access to solar-powered irrigation enables year-round farming, overcoming seasonal limitations linked to high diesel costs. In urban areas, shared solar energy solutions provide an affordable and reliable alternative to unstable power grids, reducing dependence on costly private generators. Cooperative models further strengthen financial resilience by ensuring that energy pricing remains predictable and controlled within the community, protecting members from external market fluctuations.

[72] Green Economy Financing Facility (GEFF), Installation of a photovoltaic power plant for an agricultural farm in Morocco.
[73] Energy Transition: The Global Energiewende, A bright light in times of crisis: Solar Power in Lebanon, 2023.
[74] Solar Quarter, Solar Energy In Tunisia: Assessing Opportunities And Navigating Challenges For Market Expansion, 2023.

Strengthening Community Development Through Collective Models

The cooperative approach to decentralized solar energy maximizes economic benefits by ensuring that financial gains are reinvested in local development projects[75]. By reducing input costs and increasing collective bargaining power, cooperatives help stabilize prices for essential goods and services. Surplus funds generated from lower energy costs are often directed towards improving local schools, healthcare facilities, and infrastructure, reinforcing long-term economic resilience. These participatory models ensure that economic growth is inclusive, allowing communities to retain control over their financial futures and benefit equitably from renewable energy investments.

Transformative Economic Potential of Decentralized Solar Energy

Across different contexts, decentralized solar projects demonstrate their ability to alleviate economic strain and unlock financial opportunities. By reducing energy costs, increasing disposable income, and fostering job creation, these projects contribute to overall economic stability. They also provide long-term financial resilience by minimizing reliance on fluctuating fuel markets and ensuring greater control over local energy resources. When combined with cooperative and participatory models, the impact of decentralized solar energy extends beyond individual households and businesses, fostering sustainable development and community-wide economic empowerment.

Economic Barriers in Low-Energy Consumption Regions

In some sparsely populated rural areas, the limited demand for electricity presents a major obstacle to the financial sustainability of decentralized solar projects. When energy consumption remains low, the revenue generated may not justify the initial investment required for solar infrastructure, such as photovoltaic panels, inverters, and storage systems. This issue is particularly pronounced in communities where economic activities are minimal or primarily subsistence-based, as the energy requirements for households and small businesses tend to be modest[76].

Additionally, the lack of industrial or commercial activities in such regions limits the potential for energy diversification and demand growth, which are essential for the long-term viability of decentralized systems. Without a sufficient customer base, operators of these systems may struggle to recover their costs, leading to difficulties in maintaining or expanding the infrastructure.

Transport and maintenance costs also tend to be higher in remote areas due to poor infrastructure and the need to import technical expertise for system upkeep. This further exacerbates the financial burden, making it challenging to achieve economies of scale that are necessary for cost reduction[77].

[75] One Earth, Crevillent – Spain's first local energy community, 2020.

[76] Jeune Afrique, Énergie solaire : en Afrique, les multinationales s'enflamment pour les mini-réseaux - Jeune Afrique, 2015.

[77] Bentaleb, N., L'électrification rurale décentralisée dans le sud, 2004.

Opportunities for Policy and Economic Solutions

Addressing these challenges requires targeted strategies to stimulate local economic activity and promote energy-intensive applications that can create demand for decentralized solar energy. For instance, supporting agricultural modernization through solar-powered irrigation systems can increase energy consumption and enhance rural productivity, as demonstrated by the case study in Morocco. Additionally, providing financial incentives for small businesses to adopt renewable energy technologies can spur local demand.

Furthermore, policymakers can promote cooperative models, as seen in Spain, where community ownership and shared energy management allowed for cost efficiencies and local reinvestment. By combining solar energy projects with broader economic development initiatives, decentralized systems can become more viable and play a transformative role in revitalizing rural economies.

ENVIRONMENTAL BENEFITS

Decentralized solar energy projects have consistently contributed to environmental sustainability by significantly reducing greenhouse gas (GHG) emissions and dependence on fossil fuels. Each of the analyzed projects demonstrates how renewable energy solutions can play a critical role in reducing carbon footprints and improving environmental conditions.

Reducing Greenhouse Gas Emissions and Environmental Risks

Decentralized solar energy projects play a key role in reducing greenhouse gas (GHG) emissions by replacing fossil fuel-based energy sources. In agricultural settings, the transition from diesel-powered irrigation pumps to solar energy eliminates diesel combustion, directly cutting emissions while also reducing environmental risks such as fuel leaks and soil contamination. Similarly, hybrid microgrids that integrate solar power with battery storage minimize reliance on diesel for backup power, lowering fuel consumption and its associated emissions. By significantly decreasing fossil fuel use, these projects support national energy strategies aimed at green development while aligning with international commitments, such as the Paris Agreement, to reduce carbon footprints[78].

Improving Air Quality and Mitigating Pollution

Solar energy solutions also contribute to improved air quality, particularly in areas where diesel generators are commonly used. By reducing fuel combustion, decentralized solar systems decrease particulate matter and other air pollutants that are harmful to human health. In urban environments, where high energy demand and unreliable grids lead to widespread generator use, transitioning to solar power helps mitigate air pollution and noise levels. This shift is particularly important in densely populated areas where pollution levels have severe health impacts. By replacing polluting energy sources with clean alternatives, decentralized solar projects contribute to broader national efforts to reduce urban and rural pollution.

[78] Global Spec, How microgrids can facilitate net zero carbon emissions | GlobalSpec, 2023.

Reducing Fossil Fuel Dependency and Promoting Energy Autonomy

Decentralized solar energy projects offer communities a reliable and environmentally sustainable alternative to fossil fuel-based power. By shifting away from grid electricity that often includes energy from fossil fuels, solar initiatives help reduce carbon footprints and demonstrate the viability of clean energy solutions. Energy autonomy is particularly strengthened in community-owned solar projects, where local populations take control of their energy needs while promoting long-term sustainability[79]. These initiatives serve as models for green rural and urban development, reinforcing the importance of renewable energy in reducing environmental harm and ensuring cleaner, more resilient energy systems.

Scaling Up Environmental Benefits Through Decentralized Solar Solutions

The environmental impact of decentralized solar projects extends beyond individual communities, contributing to global efforts to mitigate climate change. By reducing reliance on fossil fuels, these projects play a crucial role in decreasing carbon emissions, while also improving air quality and reducing pollution-related health risks. Whether implemented in agriculture, rural communities, or urban centers, solar energy solutions offer a scalable approach to addressing environmental challenges while supporting national and international sustainability goals, such as the United Nations Sustainable Development Goals (SDGs).

KEY SUCCESS FACTORS

Several critical factors have contributed to the success of these decentralized solar energy projects, offering valuable insights for similar initiatives in the Euromed region.

Community Participation and Empowerment

A high level of community involvement has proven essential for project success. In Spain, the cooperative model enabled residents to take charge of their energy needs, fostering a sense of shared responsibility and empowerment. Tunisia's project included local training programs, allowing residents to play an active role in maintaining the solar infrastructure. This sense of empowerment helps ensure long-term project sustainability, as communities are more likely to maintain and protect infrastructure that they helped create and manage.

Ownership structures have a significant impact on the viability and acceptance of decentralized solar projects. In Spain and Morocco, cooperative and community-owned models encouraged collective investment and reinforced trust among stakeholders. Community-owned models typically ensure that generated energy benefits stay within the community, increasing acceptance and support for renewable energy initiatives. In contrast, the public-private model used in Tunisia, where ownership and responsibility were shared between community members and local authorities, allowed for additional resources and support, making the project feasible even in a low-income setting.

[79] European Investment Bank, Spain renewables projects strengthen Europe energy autonomy, 2023.

Supportive Policy Frameworks

Government and policy support were critical in ensuring the success of these projects. Tunisia's project benefited from subsidies and training programs provided by international donors and government partnerships, reducing upfront costs and providing essential technical support. In Morocco, the agricultural cooperative received funding from regional agricultural development policies aimed at enhancing sustainability in farming practices. While Lebanon faced more regulatory challenges, the local municipality's support played a crucial role in moving the project forward, underscoring the importance of local government collaboration. These examples show that supportive policies, such as subsidies, incentives, and streamlined permitting, are essential for fostering a conducive environment for decentralized solar projects.

By examining these success factors, this study highlights the essential conditions for scaling and replicating decentralized solar energy projects throughout the Euromed region. Community-driven models with accessible ownership structures, coupled with supportive policy frameworks, can maximize the socio-economic and environmental benefits of decentralized renewable energy. The lessons learned from these case studies provide actionable insights for future renewable energy projects that aim to prioritize both equity and sustainability.

POLICY ANALYSIS

REGULATORY FRAMEWORKS FOR RENEWABLE ENERGY AND COMMUNITY EMPOWERMENT

The renewable energy policy landscape in the Euromed region varies significantly across different country groupings, reflecting diverse approaches to promoting renewable energy and community empowerment[80].

European Union Countries

EU member states operate under a unified legislative framework that fosters renewable energy deployment with a particular emphasis on decentralized solar energy solutions. The Renewable Energy Directive (RED) establishes common rules and ambitious targets aimed at increasing the share of renewable energy across all sectors of the economy, while actively promoting local initiatives and community-based solar projects. In its 2023 revision, the EU raised its binding renewable energy target for 2030 to at least 42.5%, with an aspiration to reach 45%[81], thereby demonstrating its commitment to advancing decentralized energy production and empowering local communities.

To accelerate the deployment of decentralized solar energy, the EU has introduced several innovative measures. Simplified permitting processes have been implemented to reduce administrative hurdles, making it easier for small-scale solar projects and local cooperatives to obtain the necessary authorizations. Furthermore, the designation of 'renewables acceleration areas' by 2026[82] is aimed at identifying and supporting regions with high potential for decentralized solar energy by providing expedited grid connections and preferential access to financing. These initiatives are complemented by the EU's Affordable Energy Action Plan, which focuses on reducing electricity bills, promoting clean energy sources, and diversifying energy suppliers to ultimately strengthen local energy autonomy.

By promoting the development of decentralized solar projects, the EU not only contributes to the overall energy transition but also supports the creation of local value, enhances community resilience against market fluctuations, and encourages greater citizen participation in energy production.

Eastern Mediterranean (East-Med) Non-EU Countries

In the Eastern Mediterranean region, there is a marked variation in the level of commitment to renewable energy development, with existing policies often favoring large-scale projects over decentralized, community-based solar initiatives. Many countries in the region have introduced measures to support

[80] National Renewable Energy Laboratory (NREL), Community Engagement and Equity in Renewable Energy Projects: A Literature Review, 2023.

[81] European Commission, Renewable energy targets Directive (RED), 2023.

[82] EC Website, Enabling framework for renewables, 2025.

renewable energy, yet the overall policy framework is frequently characterized by complex regulatory procedures and limited financial incentives that impede the rapid growth of small-scale solar projects. These obstacles hinder local cooperatives and small businesses from accessing the capital and streamlined approvals needed to invest in decentralized solar solutions.

To address these challenges, collaborative efforts with international organizations such as the International Renewable Energy Agency (IRENA) and other regional development bodies are actively promoting policy reforms and capacity-building initiatives. These initiatives aim to simplify permitting processes and enhance financial support through innovative financing mechanisms like grants and targeted subsidies, specifically designed to benefit decentralized solar projects. Additionally, capacity-building programs focus on equipping local stakeholders with the necessary technical and managerial skills, thereby empowering communities to lead and sustain their own renewable energy initiatives.

By streamlining regulatory frameworks and improving access to finance, these collaborative efforts create a more conducive environment for renewable energy investments in the region. This approach not only accelerates the overall energy transition but also ensures that the benefits of renewable energy—such as reduced operational costs, enhanced energy security, and increased local employment—are more widely shared across communities. Ultimately, fostering an enabling policy environment for decentralized solar energy is critical for achieving a resilient and inclusive energy future in the Eastern Mediterranean region.

Middle East and North Africa (MENA) Countries

MENA countries possess significant renewable energy potential and have increasingly recognized the importance of transitioning to a renewables-based energy system to meet growing energy demand, stimulate economic growth, and achieve decarbonization objectives[83]. However, the region faces persistent challenges, including the widespread prevalence of fossil fuel subsidies that distort market incentives and delay necessary power sector reforms. These subsidies not only inhibit investment in renewable energy technologies but also complicate the integration of decentralized, community-based renewable energy projects into the broader energy mix.

Efforts are underway to phase out these subsidies and implement policies that better support renewable energy deployment[84] across the region. International collaborations play a crucial role in this process, with partnerships between the International Renewable Energy Agency (IRENA) and regional organizations working to strengthen policy and regulatory frameworks. These initiatives focus on streamlining permitting processes, providing targeted financial incentives, and enhancing capacity-building efforts to create a more conducive environment for renewable energy investments, particularly for decentralized systems that empower local communities.

[83] Francesco La Camera, IRENA, MENA's Transforming Role in an Evolving Energy Landscape, 2023.

[84] IRENA, North Africa: Policies and finance for renewable energy deployment, 2023.

In summary, while the Euromed region exhibits a diverse policy landscape for renewable energy, common challenges include the need for simplified regulatory frameworks and increased support for decentralized renewable energy initiatives. International organizations such as IRENA, the Union for the Mediterranean (UfM), and the Organisation for Economic Co-operation and Development (OECD) are instrumental in facilitating policy development, offering technical assistance, and promoting regional cooperation. Their collective efforts are vital to overcoming existing barriers, accelerating the adoption of renewable energy technologies, and ensuring that the transition to a renewables-based energy system delivers broad economic and environmental benefits across the region[85].

BARRIERS TO THE ADOPTION OF DECENTRALIZED SOLAR ENERGY SYSTEMS

Decentralized solar energy systems hold great potential for advancing sustainable energy solutions, particularly in the Euromed region. However, their adoption is hindered by several key barriers, including regulatory complexity, financing challenges, technical and logistical limitations, and issues related to energy storage. Addressing these barriers is crucial to scaling these systems and maximizing their impact[86].

Regulatory Complexity

Complex permit processes and restrictive grid access regulations remain significant hurdles for decentralized solar projects. In many Euromed countries, existing regulatory frameworks are designed to favor centralized energy systems, leaving decentralized initiatives to navigate cumbersome administrative requirements. These barriers disproportionately affect low-income communities and small enterprises, limiting their ability to participate in renewable energy transitions. Policies that streamline permitting processes and provide clear guidelines for grid integration could significantly enhance the feasibility of decentralized solar installations[87].

Financing Challenges

The financial barriers to adopting decentralized solar systems are substantial. High upfront costs for purchasing and installing solar equipment, combined with limited access to affordable loans or subsidies, make it challenging for communities to invest in these projects. Many small-scale developers and cooperatives face difficulties securing financing due to inadequate credit mechanisms or a lack of tailored financial products. Expanding access to low-interest loans, grants, and public-private partnerships could alleviate this challenge and make decentralized solar systems more accessible to underserved populations[88].

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85 IRENA, IRENA and RCREEE Strengthen Energy Transition Collaboration in MENA Region, 2022.

86 Yaqoot, M., Diwan, P. et Kandpal, T. C., Review of Barriers to the Dissemination of Decentralized Renewable Energy Systems, 2016.

87 *Ibid.*

88 13th International Conference on Industrial Engineering and Operations Management, Exploring the Barriers to Implementing Solar Energy in an Emerging Economy: Implications for Sustainability, 2023.

Technical and Logistical Limitations

In rural and remote areas, a lack of technical expertise to maintain decentralized solar systems poses a critical obstacle. Without trained personnel to handle installation, maintenance, and troubleshooting, these systems risk becoming unsustainable in the long term. Investing in workforce training programs and capacity-building initiatives for renewable energy could address this gap. Training local technicians would not only ensure the longevity of decentralized systems but also create job opportunities in rural communitie[89].

Energy Storage Constraints

One of the most critical technical challenges for decentralized solar systems is energy storage. Batteries play a crucial role in balancing supply and demand, but current technologies present several limitations. The dominance of lithium-ion batteries in the market raises concerns due to their high upfront cost, which can be prohibitive, especially for small-scale projects and low-income communities. Additionally, the price volatility of raw materials such as lithium and cobalt further complicates long-term financial planning for decentralized solar initiatives[90].

Beyond their high initial cost, lithium-ion batteries have a limited lifespan, typically ranging between 5 and 10 years depending on usage, environmental conditions, and maintenance. After this period, their efficiency declines significantly, requiring costly replacements that can undermine the financial sustainability of decentralized solar projects. Furthermore, alternatives such as lead-acid or sodium-ion batteries offer lower costs but come with trade-offs in terms of lifespan and efficiency. Without proper financial planning and technological advancements in energy storage, decentralized solar projects may struggle to remain viable in the long term[91].

The issue of end-of-life battery management remains a significant challenge for decentralized solar systems. Many regions in the Euromed lack adequate recycling infrastructure, making it difficult to safely recover and repurpose valuable materials such as lithium, cobalt, and nickel. The improper disposal of batteries can lead to environmental contamination, including soil and water pollution, exacerbating the long-term sustainability concerns of solar projects. Additionally, photovoltaic (PV) panels themselves have a limited lifespan (typically 25-30 years) and will require large-scale recycling solutions in the near future. Strengthening local recycling industries, promoting circular economy models, and investing in sustainable alternatives such as second-life battery applications are essential for minimizing the environmental impact of decentralized solar energy[92].

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[89] Renewable and Sustainable Energy Reviews, Review of barriers to the dissemination of decentralized renewable energy systems, 2016.

[90] Koks, E. E., van Vliet, M. T. H., and Bierkens, M. F. P., The cost of reliability in decentralized solar power systems in sub-Saharan Africa | Nature Energy, 2019.

[91] U.S. Department of Energy, Office of Technology Transitions, Solving Challenges in Energy Storage, 2019.

[92] Energy Observer Productions, Le recyclage des panneaux solaires : un défi de taille | Energy Observer, 2021.

POLICY RECOMMENDATIONS TO FACILITATE DECENTRALIZED SOLAR ENERGY SYSTEMS

Simplifying Regulations and Expanding Financial Incentives

To promote the equitable and widespread adoption of decentralized solar energy systems in the Euromed region, it is essential to introduce simplified regulatory procedures specifically tailored for small-scale and community-owned solar projects. Reducing administrative burdens and streamlining approval processes will enable faster implementation and make solar initiatives more accessible to local actors, particularly in rural and disadvantaged areas. In parallel, expanding financial incentives—such as grants, low-interest loans, and tax breaks—will play a key role in stimulating investments in decentralized solar energy, ensuring that the benefits of the energy transition are distributed equitably and bridging socio-economic gaps in energy access.

Advancing Technological Innovation and Environmental Sustainability

Ensuring the long-term viability of decentralized solar systems requires policies that support research and development in advanced energy storage technologies, such as solid-state batteries or flow batteries. These innovations will help overcome the inherent intermittency of solar energy by enhancing storage capacity and extending battery lifespan, thereby making decentralized solar systems more reliable and economically viable. Additionally, establishing mandatory recycling programs for end-of-life solar panels and batteries is crucial to address environmental challenges related to electronic waste. Such programs will foster a circular economy by facilitating the reuse of valuable materials, further reinforcing environmental sustainability.

Promoting Regional Collaboration and Evidence-Based Policy Making

Maximizing the impact of decentralized solar energy policies in the Euromed region calls for enhanced regional cooperation. Cross-border collaboration is vital for sharing best practices and harmonizing regulatory frameworks, thereby increasing system compatibility and encouraging investment in transnational projects. In line with these objectives, it is essential to collect and publish comprehensive statistics on the economic and social impacts of decentralized solar energy initiatives—data that includes cost comparisons with centralized systems, job creation metrics, and measures of social equity improvement—to support evidence-based policy adjustments and enhance transparency and accountability in public decision-making.

Recent developments have added further momentum to this cooperative approach. The European Commission's Trans-Mediterranean Energy and Clean Tech Cooperation Initiative[93] establishes new platforms for joint research, technology transfer, and investment between European and Mediterranean partners. This initiative can accelerate the deployment of decentralized renewable energy projects while reinforcing regional energy security and fostering innovation in clean technology.

93 European Commission, *'Speech on Trans-Mediterranean Energy and Clean Tech Cooperation Initiative',* European Commission Press Corner, VP Suica delivers a keynote speech on Mediterranean - EPP.

Complementing this top-down effort, the TERAMED initiative[94], a civil society–led endeavor, plays a critical role in bridging the gap between local communities and policymakers. By advocating for policy reforms that support decentralized solar energy solutions and by facilitating the systematic collection and dissemination of key performance data, TERAMED empowers grassroots participation and ensures that the social and economic benefits of renewable energy projects are widely shared. Together, these initiatives exemplify an integrated strategy that leverages both high-level regulatory support and community-driven engagement, ultimately fostering a resilient, inclusive, and sustainable energy landscape in the Euromed region.

[94] TERAMED Initiative, '*TERAMED Initiative*', TERAMED Initiative website.

CONCLUSION

KEY FINDINGS

This research has highlighted that decentralized solar energy holds substantial potential for advancing both energy equity and sustainable development in the Euromed region. However, significant challenges remain, including high initial costs, limited battery lifespan, and end-of-life recycling issues, particularly in regions with inadequate waste management infrastructure. Additionally, in low-population density areas, the economic viability of decentralized systems may be limited. Addressing these barriers through targeted policy reforms, investment in local capacity-building, and advancements in energy storage technology could enable decentralized solar energy to play a transformative role in empowering communities and enhancing regional energy equity.

IMPLICATIONS FOR CLIMATE ACTION AND SUSTAINABLE DEVELOPMENT IN THE EUROMED REGION

By tapping into the abundant solar resources available across this region, decentralized solar energy systems can significantly reduce reliance on fossil fuels, helping countries meet their climate targets and reduce greenhouse gas emissions. The deployment of community-based solar projects aligns with sustainable development goals by addressing energy poverty, creating local employment, and fostering economic growth in marginalized areas. Moreover, this shift toward decentralized systems can enhance resilience against climate-related disruptions to centralized power grids, offering a more robust energy supply for vulnerable regions. Embracing decentralized solar energy as a key component of climate policy could thus advance both environmental goals and social well-being, promoting a sustainable, low-carbon future that benefits all.

POTENTIAL OF DECENTRALIZED SOLAR ENERGY SYSTEMS TO FOSTER SOCIAL AND TERRITORIAL EQUITY

Decentralized solar energy systems present a unique opportunity to empower local communities by giving them greater control over their energy resources. These systems can promote social equity by enabling access to affordable, reliable energy for low-income and rural communities often underserved by centralized power infrastructure. Decentralized solar projects can also support territorial equity by reducing disparities between urban and rural regions in energy access and economic development. Community ownership or cooperative models further enhance this potential, as they enable communities to directly benefit from energy savings and revenues generated by local solar installations. By decentralizing energy production and distribution, solar systems can help foster a more equitable energy landscape across the Euromed region, strengthening community resilience and participation in sustainable development.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should develop region-specific strategies for scaling decentralized solar energy, with particular attention to the social, economic, and environmental impacts of different ownership and financing models. More empirical studies are needed to assess how decentralized solar projects affect employment, poverty reduction, and territorial cohesion, especially in rural and underserved areas.

A key gap in the Euromed literature is the limited evidence on the social equity outcomes of community-owned systems. While theory suggests strong benefits for participation and empowerment, concrete case studies from the region remain scarce.

Further work should also analyse the broader economic effects of decentralized solar energy, including its influence on local economic activity, migration patterns, and access to essential services. Such insights would be valuable for policymakers seeking to use decentralized energy as a tool for balanced regional development.

Research on innovative financing mechanisms—such as microfinance, cooperative models, and green bonds—could help address persistent funding barriers. Comparative policy studies would also clarify how regulatory differences across Euromed countries shape the adoption of decentralized energy systems and could identify best practices for scaling up.

Finally, pilot projects and detailed case documentation are essential to capture lessons from community-led solar initiatives. A regional knowledge-sharing platform involving governments, private actors, NGOs and communities could support this effort. Improved data collection on costs, job creation, and social equity outcomes will be critical for evaluating impacts and guiding future policy design.

REFERENCES

INSTITUTIONAL REPORTS AND WHITE PAPERS

International Renewable Energy Agency (IRENA), *Fostering Livelihoods with Decentralised Renewable Energy: An Ecosystems Approach,* 2022.

International Renewable Energy Agency (IRENA), *Decentralised Solar PV: A Gender Perspective,* 2024.

International Energy Agency (IEA), *Financing Clean Energy Transitions in Emerging and Developing Economies,* 2021.

International Renewable Energy Agency (IRENA), *Renewable Energy for Remote Communities: A Guidebook for Off-Grid Projects,* 2023.

CASE STUDIES AND REGIONAL REPORTS

Friends of the Earth Europe, *Community Energy in Spain Briefing,* 2020.

World Bank Group, *Green Energy Production in Tunisia,* 2023.

High Atlas Foundation, *Harnessing the Sun: Capitalizing on Morocco's Most Abundant Resource to Power Transformative Solar-Powered Irrigation Systems,* 2021.

Global Observatory on Non-state Climate Action, *Satisfying New Renewable Energy Demands: Souss-Massa, Morocco*, 2019.

Arab Reform Initiative, *Town Hall Meetings Summary: Lebanon's Solar Energy Boom,* 2024.

POLICIES AND REGULATIONS

European Union. (2018). *Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II).* Official Journal of the European Union, eur-lex.europa.eu.

Moroccan Agency for Sustainable Energy (MASEN). (2022). *Legislative and regulatory framework for the energy sector in Morocco,* www.masen.ma.

ONLINE SOURCES

Union for the Mediterranean (UfM), https://ufmsecretariat.org.

Interreg Euro-MED, 'Interreg Euro-MED Programme', https://interreg-euro-med.eu.

Interreg Next-MED Programme, https://www.interregnextmed.eu

International Energy Agency (IEA), https://www.iea.org.

European Investment Bank, https://www.eib.org.

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