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Solar in Remote Applications in the U.S.: Challenges & Implications for Local Solar Policy

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About Meister Consultants Group, Inc.

Meister Consultants Group, Inc. (MCG) is an international sustainability consulting firm based in Boston specializing in renewable energy policy, energy efficiency, climate adaptation, corporate sustainability and international green growth. MCG is a member of the SunShot Solar Outreach Partnership (SolarOPs), a U.S. Department of Energy funded program designed to help accelerate solar energy adoption on the local level by providing timely and actionable information to local governments. In this capacity, MCG has engaged thousands of municipal officials, planners, utility officials and others at over two dozen national and regional workshops across the country. MCG also provides customized technical assistance to local governments working to streamline and standardize permitting processes, improve planning and zoning codes and regulations, and expand access to financing options for solar technologies.

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Introduction

> "Faced with rising diesel prices and a growing import dependency, remote communities can unlock a number of both monetary and non-monetary benefits from the development of local renewable energy resources. These benefits include enhanced energy security, decreased environmental impact, climate mitigation, greater self-reliance, as well as lower electricity, transportation and heating/cooling costs."[1]

Since the landfall of Hurricane Sandy in October 2012, municipalities and jurisdictions in the United States have been increasingly focused on the vulnerability of their electricity infrastructure and enhancing resilience to extreme events. Renewable energy and distributed generation resources have a critical role to play in increasing the resilience of electric grids. In remote areas and on islands, these issues have risen to the forefront, because remote electric grids function in near isolation, making grid reliability, electricity supply, cost controls and stability essential. The increasing accessibility of renewable energy systems has led to an interest in integrating solar, wind and hydro projects into remote electricity grids. The integration of such resources into smaller, isolated grids poses unique challenges given the relatively high penetration rates of solar photovoltaics (PV). In the U.S. these remote locations include Hawai'i, Puerto Rico, Guam, Northern Mariana Islands, American Samoa, and the U.S. Virgin Islands, communities off the coast of Maine and Massachusetts, mainland communities in Alaska, and even U.S. government installations such as national parks and military bases. Policy makers and planners interested in furthering grid resilience and increasing reliance on renewable energy resources can learn from the opportunities and challenges facing remote communities as they work to shift their generation mix to higher levels of solar PV.

[1] See Rickerson et al. 2012, Renewable Energy for Islands and Remote Regions, IEA-RETD, p.16: http://iea-retd.org/wp-content/uploads/2012/06/IEA-RETD-REMOTE.pdf

Current Context

A major challenge across remote and island regions is their heavy reliance on imported energy, particularly diesel fuel. The current cost of diesel-based electricity generation ranges from USD $0.25/kWh for the largest systems, to over USD $1.50/kWh for small, remote systems. In regions where tariffs fully reflect generation costs (which include most of the United States and associated territories), it is not uncommon to see generation costs between USD $0.35 – $0.60/kWh. Current residential retail rates vary from $0.37/kWh in Hawai'i, to $.51/kWh in the U.S. Virgin Islands,[2] while in the most remote regions in Alaska, where diesel must be delivered by air, rates can exceed $1.70/kWh.[3] By comparison the average U.S. retail rate is $0.11/kWh.

One of the factors driving interest in accelerating the development of solar PV in remote regions is that while diesel prices have remained high in recent years, renewable energy costs have decreased rapidly. As International Renewable Energy Agency (IRENA) Secretary General Adnan Amin recently stated, renewable energy sources are "increasingly the most economical solution for new grid-connected capacity where good resources are available."[4] Recent analysis shows that grid-connected solar PV generation costs now range from USD $0.12 – 0.25/kWh depending on the location, resource quality, and overall balance of system costs.[5] The added urgency of strengthening local grids and resiliency, combined with the rapid downward trend in PV costs is also boosting interest in micro-grids as an alternative to large, centralized generation and distribution networks.

The integration of renewable resources into remote electricity grids is not only cost-effective, but it can also increase system resilience. Increased deployment of renewable and distributed generation technologies with islanding capabilities can increase the flexibility of electricity infrastructure and reduce demand dependence on the grid.

Despite the increasingly favorable economics, a host of factors continue to prevent wider adoption of solar PV in remote regions in the U.S. These include, but are not limited to:

- High upfront cost of solar PV systems
- Lack of economies of scale
- Absence of consistent policy and regulatory support
- Persistence of high soft costs (e.g. permitting, labor, etc.)
- Lack of knowledge (e.g. regarding the operation and maintenance of hybrid solar/diesel systems or micro-grids)
- Limited access to capital
- High cost of materials (e.g. building supplies, food)

Although island and remote communities, because of their unique characteristics, are where the economic argument for solar PV is most compelling, a variety of factors, including the barriers listed above, make these communities areas where solar PV remains most challenging to deploy.

Part I of this brief looks at the opportunities and challenges for remote communities in the U.S. to adopt solar PV, while Part II focuses more specifically on the policies and strategies that facilitate adoption of solar PV in these regions and the implications for non-remote communities.

[2] "U.S. Virgin Islands Water and Power Authority (WAPA)," accessed June 18, 2014, http://www.viwapa.vi/Home.aspx.

[3] See http://www.akenergyauthority.org/PDF%20files/pcereports/fy12statisticalrptcomt.pdf

[4] (Financial Times, January 14 2013).

[5] Energy Information Administration Annual Energy Outlook 2014 with projections to 2040.

Part 1: Overview of Opportunities and Challenges

Understanding Remote Communities

Remote communities are defined by a lack of interconnection to central infrastructure such as roads, pipelines, and transmission lines and are highly susceptible to factors beyond their control such as extreme weather events and seasonal changes that impact their access to energy.[6]

From an energy standpoint, they generally exhibit a heavy reliance on liquid fuels (primarily diesel) for power and transportation needs.[7] As a result, remote regions face significantly higher energy costs than mainland regions, and in general, lower quality and consistency of energy supply.

Another important set of factors that often characterize remote communities is that:

- Energy usage is highly seasonal by nature (e.g. high winter heating loads or electricity demand that varies with tourism)
- Many are experiencing out-migration as people move closer to larger urban centers
- Each community has a unique culture and history, and
- Many face difficulties retaining skilled labor.

This section takes a look at the opportunities and challenges of developing solar PV in remote regions of the U.S.

Opportunities

The higher costs of energy service in remote regions combined with highly site-specific loads make them ideal candidates for deploying solar PV to displace diesel use. Projects can be sited and scaled to serve on-site loads, allowing imported diesel to kick-in only when it is necessary to supplement local resources.

This section divides the landscape into two basic areas: islands, and remote communities, and analyzes each in terms of the opportunities they present, drawing on examples where possible.

Islands. Islands provide a microcosm of how to balance supply and demand in small power systems.[8] They differ from mainland micro-grids in that they often lack an interconnection to an external grid network. Islands are heavily reliant on expensive imported oil for energy production, yet often have an abundant solar resource. While each island will have unique challenges and opportunities, there are common variables that most islands share in terms of energy access, cost and infrastructure. To better coordinate and facilitate developing solutions, the International Renewable Energy Agency (IRENA) was tasked with creating the global Renewable Energy Islands Network (GREIN). Comprised of 48 island nations, GREIN serves as a central location for sharing best practices, knowledge development and research to facilitate the adoption of renewable energy on islands.[9] The United States, with its diverse geographies and communities is taking similar approaches through initiatives

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[6] In early 2012 the city of Nome in Alaska experienced an unusually cold winter, which caused the harbor to "ice up" sooner than anticipated and interrupted fuel deliveries. Special icebreakers had to be used to deliver the fuel. See Yardley, W. (2012, January 13). Tanker with crucial fuel delivery is sighted off Nome. *New York Times.*

[7] See Rickerson et al. 2012, p.25: http://iea-retd.org/wp-content/uploads/2012/06/IEA-RETD-REMOTE.pdf

[8] IRENA GREIN "Renewable Islands: Settings for Success." (International Renewable Energy Agency, (2014). Available at: http://www.irena.org/DocumentDownloads/Publications/GREIN_Settings_for_Success.pdf

[9] Id.

such as the recently launched *Islanded Grid Wind Regional Resource Center* through the U.S. Department of Energy. Similar to GREIN, this initiative will share information related to wind and wind-diesel hybrid systems, and other best practices among islands and remote communities across the U.S.[10] The Department of Interior Office of Insular Affairs has also sponsored sustainable energy planning in U.S. island jurisdictions.[11] The opportunities for solar PV in island regions will differ based on a range of factors, including how large, concentrated, and populous the islands are, as well as their overall load profiles.

The Hawaiian islands of Oahu, Maui and Kauai already have significant solar and wind resources integrated into their grids. For example, as of earlier this year Oahu reached PV penetration rates of 10%.[12] Additionally, in terms of total installed solar power per customer, Hawaiian Electric, Kauai Island Utility Cooperative and Maui Electric ranked in the top ten utilities nationwide.[13] In part due to these high PV penetration rates and the associated technical challenges, the NREL and Hawaii Clean Energy Initiative recently conducted experimental modeling to understand the performance of the two island grids with even higher renewable penetration (20%). Though the generation mix on Oahu and Maui differs, high solar energy penetration increased operational challenges in both cases, which were managed in the model using a series of mitigation strategies. A few of the options they outlined include relaxing the operating schedule for baseload units and demand response measures, and upgrading combined-cycle units for greater flexibility and to reduce the need to curtail wind and solar power. Adding additional distributed solar generators as opposed to a centralized solar plant also decreased the variability of the system, since cloud cover and other weather phenomenon were less likely to affect all distributed resources at once.[14]

Hawaii Clean Energy Initiative (HCEI)

Launched in 2008, the HCEI is a leading example of combining a holistic analysis of energy supply and demand, and developing a strategy drawing on both energy efficiency and renewable energy to reduce reliance on energy imports. The goals of the HCEI are to supply approximately 40% of the total electricity mix with renewable energy sources by 2030, combined with improvements in energy efficiency of 30%. The initiative involved close collaboration between leading research institutes, as well as existing utilities, and stakeholders.

[10] "Department of Energy Boosts Island Renewable Energy Efforts | Alaskarenewableenergy.org," accessed June 18, 2014, http://alaskarenewableenergy.org/department-of-energy-boosts-island-renewable-energy-efforts/.

[11] See: Conrad, and Esterly. "Guam Strategic Energy Plan." Sponsored by the Dept. of Interior Office of Insular Affairs and the Guam Energy Task Form. (July 2013). Available at: http://www.nrel.gov/docs/fy13osti/59192.pdf

[12] Eric Wesoff, "How Much Solar Can HECO and Oahu's Grid Really Handle? Testing the Limits of a Large Island's Electrical Grid with 10 Percent PV Penetration," *GreentechMedia.com*, February 10, 2014, http://www.greentechmedia.com/articles/read/How-Much-Solar-Can-HECO-and-Oahus-Grid-Really-Handle.

[13] Edgar Meza, "Hawaiian Electric Affirms Commitment to Solar," *Pv Magazine*, April 25, 2014, http://www.pv-magazine.com/news/details/beitrag/hawaiian-electric-affirms-commitment-to-solar_100014914/.

[14] See, NREL 2013, Hawaii Solar Integration Study: Executive Summary. Available at: http://www.nrel.gov/docs/fy13osti/57215.pdf.

A recent example of integrating solar PV in a small island context is the 307kW solar PV system installed on Alcatraz Island, the site of the famous former penitentiary (and now part of the U.S. National Park Service) in San Francisco. This system now generates approximately 400MWh of renewable power per year, and substantially reduces diesel use on the island, helping save tens of thousands of dollars per year on imported fuels.[15]

Another example can be found in the U.S. Virgin Islands, where the Virgin Islands Water and Power Authority (WAPA) recently signed Power Purchase Agreements worth 18 MW of solar energy covering its territory, which represents about 15% of its peak load demand.[16] These efforts are aimed at meeting the Islands' requirement of reducing its fossil fuel consumption by 60% by 2025 and generating 30% of its peak demand from renewable sources by 2025, as well as reducing the high costs of electricity, which account for an estimated 9% of residents' income, compared to 2% of those on the mainland.[17],[18] These systems are contributing directly to reducing diesel imports and introducing long-term cost savings for the local government. These and many other examples suggest that regardless of the PV penetration levels, solar PV system are generally a cost-effective way to promote more renewable energy in remote locations, and even at high penetration levels can be adopted safely and efficiently.

Remote Communities. While there are remote communities scattered across the U.S., most mainland regions have been grid-connected for decades. One exception to this remains Alaska, which has over 200 utilities in total, over 150 of which serve communities with no grid tie to the larger network that runs along the historic "Rail Belt." Many of these communities are focused largely on traditional industries such as fishing, hunting, and mining, and many have fewer than 400 residents.

Utilities in Alaska use a variety of fuel types, including residual fuel oil, distillate fuel oil (i.e. diesel), jet fuel, naphtha, and Heavy Atmospheric Gas Oil (HAGO), each of which has unique characteristics and heat content.[19] Due to heavy reliance on oil-based fuels with a lack of interconnection to natural gas pipelines or central power grids, remote regions find reliable, year-round electricity service extremely costly. For instance, in 2011, diesel fuel prices in Alaska ranged from approximately $3.00/gallon to over $7.50/gallon in the most remote regions.[20] Local and state governments have developed a range of different subsidy programs to mitigate the high costs of electricity service in these regions.

The largest of programs in the U.S. is Alaska's Power Cost Equalization (PCE) program, with a goal to "equalize the high cost of electricity in rural communities with the lower costs in more urban areas."[21] In 2011, 186 communities in Alaska benefited from the PCE program The per-kWh subsidy ranges from as little as $0.02 per kWh for certain coastal communities to as much as $0.81 per kWh for the

[15] http://www.solarserver.com/solar-magazine/solar-news/current/2012/kw30/us-national-park-service-installs-307-kw-pv-system-on-alcatraz-island.html
[16] Vladimir Pekic, "Toshiba Breaks Solar Ground in Virgin Islands," *Pv Magazine*, August 21, 2013, http://www.pv-magazine.com/news/details/beitrag/toshiba-breaks-solar-ground-in-virgin-islands_100012458/.
[17] "U.S. Energy Information Administration - USVI," accessed June 18, 2014, http://www.eia.gov/state/analysis.cfm?sid=VQ.
[18] See, NREL 2012, p.35. Available at: http://www.nrel.gov/docs/fy12osti/53188.pdf
[19]See http://iser.uaa.alaska.edu/Publications/2012_11-AlaskaEnergyStatisticsCY2011PreliminarySummary.pdf
[20] See http://www.akenergyauthority.org/PDF%20files/pcereports/fy12statisticalrptcomt.pdf
[21] See http://www.akenergyauthority.org/PDF%20files/PCEProgramGuide_June09.pdf

most remote inland villages. In communities like Lime Village, AK, this still leaves residential customers paying over $0.90 cents per kWh for electricity, over six times the cost of a residential customer in Boston, one of the more expensive markets in the lower forty-eight.

Similar programs are common for rural and remote areas, both in the U.S. and around the world, to help reduce the *price* of electricity for residents living in these regions. However, such programs do little to reduce electricity *cost*.

Bering Strait Native Corporation, Alaska

In 2008, the BSNC installed a 16.8kW solar PV system on their building on the Seward Peninsula in Alaska. The solar PV system currently reduces diesel use by approximately 1000 gallons per year, generating energy savings between $3,000 and $4,000 per year. At this rate, the owners should be able to recover their costs within five to seven years.

The wide variety of renewable energy resources in Alaska makes it possible to develop a wide range of hybrid configurations using renewable energy resources, including substantial hydro power and biomass resources along the southern coast, along with geothermal, wind, and solar PV.[22] As is often pointed out, the solar PV resource in Anchorage is comparable to that in much of Germany, which remains the world's largest solar market. Significant opportunities also exist to increase the share of solar PV in remote regions and national park sites in the U.S., such as in Arizona, Nevada, New Mexico, and Utah.[23]

Challenges:

As mentioned above, due to the declining costs of solar PV and the relatively high costs of diesel and other fossil fuels, opportunities for further deployment of solar are numerous. Studies have shown that the LCOE of solar is cost-competitive with diesel and that by simply adding low levels of PV a community can enjoy significant cost savings, in addition to the environmental and health benefits of lower carbon emissions. Areas with lower penetrations of solar PV can reasonably integrate solar without substantial technical problems, especially if combined with existing diesel generators that can easily ramp up or down depending on the level of solar energy. While these opportunities present significant benefits to remote and island communities, achieving higher penetrations of solar PV (upwards of 20-30%) will be difficult without investment to upgrade the existing grid technology and develop storage capabilities.[24]

Despite these promising trends, developing solar PV in remote regions to achieve high levels of penetration (20-30% of system loads) poses a number of challenges due to the intermittent nature of solar energy. One way to mitigate this problem is to combine the solar systems with sufficient storage capacity. The drawback to this approach is the relatively high capital costs of storage systems and the

[22] Alaska Energy Authority. "Renewable Energy Atlas of Alaska. April 2013. See: http://www.akenergyauthority.org/PDF%20files/2013-RE-Atlas-of-Alaska-FINAL.pdf
[23] For an example, see: http://www.nps.gov/nabr/planyourvisit/solarpower.htm
[24] Wilson Rickerson et al., *Renewable Energies for Remote Areas and Islands (REMOTE)* (Paris, France: International Energy Agency Renewable Energy Technology Deployment (IEA-RETD), 2012), http://iea-retd.org/wp-content/uploads/2012/06/IEA-RETD-REMOTE.pdf.

challenges of servicing and replacing the batteries as needed, given the logistical and technical challenges remote communities face.

Second, where batteries are deployed at scale, they can add between 30-50% to total solar PV supply costs (and in some cases even more as module costs decline and battery replacements are factored in),[25] making remote PV systems more expensive than their grid-connected counterparts. However; it should be noted that levelized cost of energy calculations that assign the cost of storage in hybrid grids only to renewable generation may be misleading.[26] Storage can also allow diesel generators to turn off and avoid "part load" operation which reduces efficiency and shortens the life of these generators.[27] Batteries can serve as a bridge to "smooth" demand even without integrating renewables.[28] Dr. Ernest Moniz, U.S. Secretary of Energy, recently stated, "Energy storage is a vital component of a more resilient, reliable and efficient electric grid;[29] a reflection of the fact that advancing energy storage has become a policy priority across the nation. "[30]

A further challenge that can arise is that distribution feeders may not be well-equipped to handle rising levels of solar PV generation, resulting in voltage and frequency issues.[31] Over-loading of distribution feeders has begun to occur more frequently in a number of markets with a growing share of solar PV such as Germany and California. In the absence of suitable demand-response capabilities, adequate storage capacity, or other technological solutions (e.g. network reinforcement, on load tap changers, advanced voltage control, etc.)[32] these issues may be difficult to resolve.

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[25] See Rickerson et al. 2012, p.25: http://iea-retd.org/wp-content/uploads/2012/06/IEA-RETD-REMOTE.pdf
[26] Id.
[27] Id.
[28] Id.
[29] See http://energy.gov/articles/energy-department-releases-grid-energy-storage-report
[30] See http://energy.gov/articles/energy-department-releases-grid-energy-storage-report
[31] See Hoke A., and Komor, P. (2012). 'Maximizing the Benefits of Distributed Photovoltaics,' *Electricity Journal*, 25(3) : pp. 1040-61.
[32] See PV Grid European Advisory Paper available at: http://www.pvgrid.eu/results-and-publications.html

Micro-Grids

Island communities are serving as test-beds for micro-grids and the issues surrounding the integration of relatively high concentrations of renewables. Micro-grids are defined as small, self-balancing grid networks that can operate on a stand-alone basis, and in some cases seamlessly connect or disconnect from the main grid as needed. As such, they are typically not as "remote" as an island or isolated communities, but some of the same principles and lessons apply. While micro-grids are increasingly common in the U.S. defense industry—accounting for more than half of all the micro-grid projects in the U.S. in 2012[1]—they can also be deployed in civilian applications such as hospitals. However; they remain comparatively rare outside of these niche markets.

The U.S. currently has approximately 1,500 MW of generating capacity in micro-grids,[2] and this number is poised to grow significantly in the years ahead as residents, businesses, universities, research labs and local governments begin to seize the new opportunities enabled by rapid improvements in micro-grid technologies. In the wake of Hurricane Sandy and other major blackout events in recent years, there is growing interest in developing micro-grids and increasing the resiliency of electrical supply systems. The State of New York recently committed $40 million to a design contest to develop ten storm-resilient community micro-grids with emergency off-grid capability.[3] In 2013 the State of New Jersey also signed a memorandum of understanding with the Department of Energy, NJ Transit and the New Jersey Board of Public Utilities, along with Sandia National Laboratories, to help design a micro-grid to power the transit system between Newark and Jersey City and Hoboken.[4]

[1] Andrea Marr and Wilson Rickerson, Generating-Security-Resiliant-Renewable-Power-for-U.S.-Military-Installations1.pdf , Center for National Policy, (April 2014).
[2] See: http://blog.rmi.org/blog_2013_07_23_microgrids_and_municipalization
[3] Id.
[4] "Energy Department Partners with State of New Jersey to Study Ways to Improve the Reliability of New Jersey's Transit System in Aftermath of Superstorm Sandy," Energy.gov, August 26, 2013, http://energy.gov/articles/energy-department-partners-state-new-jersey-study-ways-improve-reliability-new-jersey-s.

Fourth, it can be difficult to optimize system operations on both a daily as well as seasonal basis. The efficiency of diesel generation declines considerably as the load factor dips below 30-35%, which can increase operations and maintenance (O&M) costs and shorten generator life.[33] As noted above integrating storage can help extend the life of generators and integrate renewables. Dealing with seasonal variations in electrical output and demand can make it difficult to properly integrate a significant share of solar PV into remote energy systems, as supply and demand can occasionally be significantly out of step with each other. This makes storage all but necessary, particularly in small power systems.

[33] In fact, many remote diesel systems already make use of battery storage even in the absence of renewable energy, to allow diesel generators to be turned off when load falls below certain load factor thresholds (e.g. at night). Battery banks then act as a bridge until load rises sufficiently to justify turning generators back on. As such, battery storage can already be considered an important part of good power system management in remote regions. See Rickerson et al. 2012: http://iea-retd.org/wp-content/uploads/2012/06/IEA-RETD-REMOTE.pdf

This point relates closely to a fifth major challenge in remote regions, namely that diesel systems are often over-sized in relation to load. When diesel systems are too large for the loads they serve, they can dip below their optimal operation level too frequently and create a host of O&M challenges. This problem is exacerbated by the fact that these remote areas are facing a combination of population loss and a decline in traditional industries such as fishing, which results in lower demand in relation to the existing generators which were sized for much larger populations and higher demand Adding solar PV in these communities, while often delivering a net cost savings, may also require a downsizing of the diesel generators to optimize system use.

Finally, seasonal factors can significantly alter the load shape and size in remote regions due to seasonal activities, including fishing and tourism. These factors may make it difficult to add significant quantities of solar PV systems to remote micro-grids, as supply may routinely exceed demand during much of the year.

All of these considerations make it necessary for local governments and utility decision-makers responsible for power supply planning in remote regions to adopt a whole systems perspective when considering how best (i.e. most cost-effectively and reliably) to integrate distributed solar PV into their power systems.

Part 2: Strategies and Policies to Accelerate Solar PV in Remote Regions

In light of the above challenges of developing solar PV in the remote regions, state and local governments are beginning to consider how they can create more supportive policy and regulatory environments to enable cost-effective solar PV adoption.

High and still rising costs of electricity in remote areas can prompt development of energy diversification strategies involving lower cost, locally available renewable energy resources. While some communities have access to abundant and untapped hydroelectric potential, others without such resource may find solar PV readily and economically competitive against existing diesel-based systems. While many Arctic communities experience prolonged periods of darkness during the winter months and would likely continue to rely on diesel and other forms of power during these periods, solar energy systems could help reduce diesel reliance for many homes and businesses during the remaining months of the year.

While balancing supply and demand on smaller systems remains challenging, it is becoming easier with innovations in smart grid technologies, greater demand response, and a combination of storage, system control, and information technologies. Together, these can provide the necessary system design elements required to flexibly manage supply and demand and make micro-grids a viable option for remote regions in the U.S.

The Role of Local Government

Local governments can take a number of important steps to allow for increased integration of solar PV and other renewable energy generation. These considerations are not just relevant for remote communities, but representative of the planning process for any community interested in increasing reliance on renewables and enhancing resilience through micro-grids and distributed generation. This section divides these actions into a high-level analysis, followed by discussions of specific action items and technical measures.

Planning Considerations	Further Questions and Details
Consider broad supply and demand characteristics of the region or micro-grid and current trends	Is demand projected to increase or decrease?
Examine renewable energy potential and its integration with PV	How would hydropower and wind resources complement solar?
Create clear targets for solar PV in future generation mixes	What kinds of impacts will increased solar PV have for system control, economics and technical operations?
View electricity supply for region holistically	Are there immediate economic and financial factors affecting supply? What is the medium and long-term resilience of the energy supply chain and the region's strategy for generation and distribution?

	What technologies are cost-effective? Are there opportunities for synergies between thermal energy, transportation and electric supply?
Explore energy efficiency improvements	How can total system load and peaks be reduced? Demand side management or new technologies?
Examine opportunities to reduce barriers through soft costs	Has there been a comprehensive review of permitting, interconnection and inspection procedures for solar? Can these processes be streamlined to reduce costs?
Consider the system impacts of solar PV integration in remote areas	Is the existing electric infrastructure (e.g. generator, control equipment, transmission and distribution assets, etc.) able to facilitate PV integration? Can generators accommodate sudden load shifts?
Remember human dimensions of energy use	What are the patterns of activity and energy use? What solutions are appropriate given the cultural context?
Engage stakeholders in identifying barriers and challenge and energy strategy development	What is the best way to reach stakeholders and receive their input? At which planning stage should outreach begin?

In addition to these high-level questions and considerations, decision-makers in remote regions may consider a number of concrete measures to increase the adoption of solar PV and reduce total systems costs and soft costs:

- **Explore ways to combine the shipment of solar PV components with the timing and scheduling of existing delivery routes**. This can reduce delivery costs, which can significantly improve overall project economics for distributed solar PV systems;
- **Develop local educational opportunities in PV system installation and maintenance**. It is often far less expensive to develop local experts than to periodically outsource maintenance and troubleshooting. Developing a common base of knowledge in the community about solar PV can reduce costs and risks of installing PV in remote communities;
- **Establish opportunities and networks for virtual training and troubleshooting.** For instance, this can involve using existing teleconference or voice-over IP video conference technologies to address basic questions and concerns. This can be coordinated with existing research institutes such as NREL and the Lawrence Berkeley National Laboratory (LBNL), as well as with industry practitioners (e.g. HOMER Energy, Power Analytics), or by drawing on experiences from residents and system engineers from other remote communities across the U.S.;

- In regions where external installers are required, **it may be possible to bundle orders together and allow for several PV systems to be installed within a single trip**. Harnessing these kinds of economies of scale through better coordination can generate significant savings, and further reduce overall installed system costs;
- **Standardization in the permitting and other processes across remote regions** (particularly in sparsely populated regions with hundreds of small communities such as Alaska) **can further contribute to reducing unnecessary costs and delays.** The same applies for simplifying interconnection standards and requirements. Both these and the overall permitting process should be made clear to residents and local business owners in a clear, readily accessible format;
- **Analyze opportunities for demand-response.** Are there opportunities for flexible loads such as chillers, agricultural pumps, or hot water heaters, which can be turned on or off remotely, to be integrated into system operations, and be correlated with solar output?
- **Consider streamlining current taxation structure for solar PV-related components.** Many countries now exempt solar modules and inverters, for instance, from certain state-level and national sales taxes. Similar steps could be taken for remote areas to leverage significant cost savings from reduced diesel use in these regions. A similar process should take place for existing subsidies. In many remote regions, fossil fuel subsidies represent a clear case of the governments sector "crowding out" the private sector by providing a costlier and less sustainable solution. Where possible, pathways to phase-out should be explored;
- **Consider ways to increase end-user awareness on battery banks operation and maintenance measures designed to prolong battery life**. The life of battery banks for solar PV systems depends critically on how the batteries are used. Preventing deep discharging is necessary to prolong battery life, which can improve overall solar PV economics in remote regions. Local governments can potentially encourage this by requiring the systems come equipped with automatic shut-off capabilities to prevent deep discharging. In hybrid configurations, this can simply involve momentarily drawing on diesel power instead;
- **It is easier to integrate solar PV into a system with many smaller, rather than a few larger, diesel units.** This allows unused units to be shut off when load requirements dip. The comparatively low cost of diesel and electric generation sets "gensets" makes this a cost-effective way to ensure adequate reliability and back-up power without running into the risks that low load factors can introduce. It can also help reduce line loss in the system, resulting in further savings. This also makes it an important priority for remote regions to minimize peak loads, and reduce financial, economic and technical issues that arise from low asset utilization. Systems with fewer and smaller peaks are more cost-effective to manage and easier to operate.

Conclusion

In recent years, solar PV costs have tumbled while diesel costs have continued to rise, thus improving the economics of solar power in remote regions of the U.S. This opens up a wide array of possibilities for citizens, businesses, and local utilities in these areas. However, despite the improving economics, adoption of solar PV in remote regions of the U.S. remains relatively modest. While reservations remain among some decision-makers about the ability of solar PV systems to replace the functions of diesel systems, thus far the 'work horses' of remote electrification worldwide, technological improvements combined with better system integration have made solar PV a cost-effective part of the electricity supply mix.

In some regions facing extremely high generation costs, such as in Alaska, the most cost-effective solutions are probably hybrid configurations, including a well-integrated mix of solar PV, wind, and hydro, potentially combined with diesel power, and some remote biomass or waste-to-energy (WTE) systems. In larger remote systems, such as in Hawai'i, a stronger focus on energy efficiency and demand response may prove the most cost-effective approach, as solar PV systems begin to become a larger part of the overall supply mix.

One of the problems that continue to limit solar PV deployment in remote regions is that systems are often installed on a one-off basis, which makes each individual project costlier both in terms of fixed and soft costs. As installers and aggregators develop more experience, installation costs can be substantially reduced through both increased installer efficiencies and overall economies of scale, which can help lower costs and lead to more affordable solar power supply for remote residents. Also, by installing a greater number of systems per year, local installers can spread their fixed costs over a larger number of projects, thereby lowering costs for customers. Increased aggregation and streamlined procedures are lessons which all governments can apply to reduce the costs of solar. Local governments should be at the forefront of this effort, as it is ultimately residents and businesses in remote areas that stand to gain in terms of lower cost energy supply, increased resiliency to external shocks, and greater overall energy independence.