ACKNOWLEDGEMENTS

The Authors would like to thank the following IEA-RETD REMOTE Project Steering Group (PSG) members for their guidance and support throughout the project:

Michael Paunescu  
Chair, Natural Resources Canada

Matthew Kennedy  
Sustainability Energy Authority of Ireland

Zitouni Ould-dada  
Department of Energy and Climate Change in the United Kingdom

Kaoru Yamaguchi  
Institute of Energy Economics in Japan

Axel Strang  
General Directorate for Energy and Climate Change in France

Dolf Gielen  
IRENA Innovation and Technology Centre

Mary Rose de Valladares  
IEA-Hydrogen Implementing Agreement

Galina Obolenskaia  
Natural Resources Canada

David de Jager  
Ecofys Netherlands, IEA-RETD Operating Agent

Kristian Petrick  
All Green Energies, Acting for the IEA-RETD Operating Agent

In addition, the Authors would like to thank a number of other experts who helped strengthen earlier versions of this report by providing us with their insights through interviews, additional information resources, and/or through review of key sections:

Hasnaoui Abdelmoghit  
Coordinateur général d'ADL-Chefchaouen

Bruno Burger  
Fraunhofer-Gesellschaft

Paul Chambers  
Department of Energy and Climate Change in the United Kingdom

Miguel Angel Fernández  
Project Manager, IDOM Ingeniería

Aleta Fowler  
Policy and Planning Advisor at the Canadian Northern Economic Development Agency

Amie Fulton  
Rural Development Council of Scotland

Maggie Fyffe  
Secretary and Key contact Isle of Eigg Heritage Trust (IEHT)

Simon Gamble  
Manager Small Renewable Asset Development, Hydro Tasmania, Australia

Hideki Hayashi, Ph.D.  
General Manager-Smart Grid Technology, Transmission & Distribution Systems Div., Toshiba Corporation, Social Infrastructure Systems Company

Paul Irving  
British Foreign and Commonwealth Office

Philippe Jacquin  
PHK Consultants, France

Ina Jakobsen  
Nordic Energy Denmark

Greg Jones  
Manager of Strategic Planning and Business Development, Nalcor Energy, NFLD, Canada

Kat Keith  
Wind-Diesel Coordinator, Alaska Center for Energy and Power, University of Alaska, USA
Amy Keuhl | Aboriginal Affairs and Northern Development Canada
Antoine Lacroix | Wind Energy Engineer, Natural Resources Canada
Mark Lambrides | Section Chief, Organization of American States (OAS)
Konrad Mauch | Principal Consultant, KM Technical Services, Canada
Neeltje Muselaers | Ministry of Economic Affairs in the Netherlands
MSc. Eng. PhD | Energy planner, energy advisor and project manager, Fuglafjørður
Vilhjálmur Nielsen | Municipality, Faroes and ENplan in Denmark
Gonzalo Piernavieja | Director of Technological Research and Development Division, Instituto Tecnológico de las Canarias (ITC)
J.P. Pinard | President, JP Pinard Consulting Engineer, Canada
Bob Schulte | Ecofys
Inger Strand Karni | Nordic Energy Denmark
Ingrid Slungaard | Enova Norway
Myklebust | Myklebust
Margaret Sorensen | Nordic Working Group
Salvador Suárez, | Chief of the Renewable Energy Department, ITC
Jøgvan Thomsen | SEV, Faroe Islands
Dr Tu’u’u Taule’alo | Former Minister, Ministry of Natural Resources and Environment, Samoa
Daniel Van Vliet | Manager, Department of Aboriginal Affairs and Northern Development Canada
Dr. Federico Villatico | IEA HIA Operating Agent for Task 29, Distributed and Community Hydrogen (DISCO H2)
ABOUT IEA-RETD

The IEA Renewable Energy Technology Deployment (IEA-RETD) was officially launched in September 2005 with five founding members. Current members of the IEA-RETD are Canada, Denmark, France, Germany, Ireland, Japan, Netherlands, Norway, and United Kingdom. The IEA-RETD’s mandate is to address cross-cutting issues that influence the deployment of renewable energy and to act as a vehicle to accelerate the market introduction and deployment of renewable energy technologies.

While the other IEA implementing agreements on renewable energy focus on specific technologies, the IEA-RETD is cross-cutting from a technological point of view and intends to complement these.

ABOUT THE IMPLEMENTING BODY (IB)

**MEISTER CONSULTANTS GROUP**

Meister Consultants Group (www.mc-group.com) is an international consulting firm founded on the principle that global best practices can inform even the most localized decisions. MCG specializes in on- and off-shore renewable energy policy design and analysis, environmental sustainability, international dialogue, and corporate responsibility. MCG is experienced with conducting renewable energy policy analyses (including siting and permitting), designing renewable energy policies, assessing international best practices, and conducting stakeholder interviews to understand how policies work on-the-ground. The lead authors from MCG are Wilson Rickerson and Jayson Uppal.

**HOMER ENERGY**

The HOMER software is the global standard for economic analysis of sustainable microgrid systems for remote power, island utilities, and microgrids, with over 66,000 users in 193 countries. HOMER was originally developed at the U.S. DOE’s National Renewable Energy Laboratory (NREL). Its developers are now the principals of HOMER Energy, which has the exclusive license. From this unique position, HOMER Energy provides a variety of services to facility managers, project developers, program planners, and technology developers to help them design cost-effective and sustainable power systems. The lead authors from HOMER Energy are John Glassmire, Peter Lilienthal, Ed Sanders and Chris Colson.

**TRAMA TECNOAMBIENTAL**

Trama TecnoAmbiental (TTA), founded in 1986 and based in Barcelona, Spain, is an international consulting and engineering company that specializes in distributed generation through renewable energy sources, energy management and efficiency, rural electrification and self-generation through distributed micro-generation, integration of renewables in buildings and sustainable construction, as well as training and technological development. TTA’s execution of numerous studies and projects worldwide has consolidated the company as a point of reference in off-grid electrification through electric microgrids using renewable generation. Since its establishment, TTA has focused all its efforts on changing the way energy is used, through substituting fossil and nuclear fuels with renewable energy, transforming the design criteria of buildings to promote energy independence, and making universal
access to electricity possible in the most disadvantaged areas. The lead authors from TTA are Mauricio Solano-Peralta and Xavier Vallvé.

**E3 ANALYTICS**

E3 Analytics is an energy consulting company specializing in renewable energy development. Through detailed analysis, it helps clients better understand the factors that are re-shaping the energy landscape worldwide, in both developed and developing countries, providing services in a host of different areas including policy, strategy, finance, and sustainability. Toby Couture is Director of Energy Analysis at E3 Analytics, and is the lead author on work conducted on this remote area study on behalf of E3.
TABLE OF CONTENTS

Acknowledgements .................................................................................................................. 2
About IEA-RETD ...................................................................................................................... 4
About the Implementing Body (IB) .......................................................................................... 4
Table of Contents ..................................................................................................................... 6

Executive Summary .................................................................................................................. 13

1. Introduction .......................................................................................................................... 17

2. Defining Remote Areas ........................................................................................................ 18
   2.1 Recommended Definition for the REMOTE Project ......................................................... 18
   2.2 Additional Considerations ................................................................................................. 19
      2.2.1 The Relationship Between Different Definitions of Remote ...................................... 19
      2.2.2 Distinguishing Between Developed and Developing Countries .................................. 20
      2.2.3 Defining “Central” Grids and “Weak” Grids ................................................................. 22

3. Renewable Energy Considerations for Remote Areas ....................................................... 23
   3.1 General Considerations ..................................................................................................... 23
      3.1.1 The Cost of Renewable Energy ..................................................................................... 23
         3.1.1.1 The Rising Cost of Diesel ....................................................................................... 23
      3.1.2 Economic Resources and Activity ................................................................................ 28
      3.1.3 Demographic trends: Population Growth, Migration and Emigration ...................... 29
      3.1.4 Availability of Trained Technicians ............................................................................... 30
      3.1.5 Logistics ......................................................................................................................... 30
      3.1.6 Economic Development Benefits ............................................................................... 31
      3.1.7 Community Acceptance ............................................................................................... 32
      3.1.8 Environmental Considerations ...................................................................................... 33
      3.1.9 Technical Considerations ............................................................................................... 34
         3.1.9.1 Energy Scenarios ....................................................................................................... 34
         3.1.9.2 Electricity .................................................................................................................... 34
         3.1.9.3 Transportation .......................................................................................................... 44
         3.1.9.4 Heating ...................................................................................................................... 46
   3.2 Specific Considerations By Category .............................................................................. 48
      3.2.1 Remote Areas with Long Winters (Category 1) ............................................................ 55
3.2.6.1 Environmental conditions ................................................................. 78
3.2.6.2 Thermal energy needs .................................................................... 79
3.2.6.3 Electricity Needs ............................................................................ 80
3.2.6.4 Transporation needs ....................................................................... 82
3.2.6.6 Case Studies .................................................................................. 83
3.2.7 Lessons Learned from Case Studies of Remote Areas .................. 83
  3.2.7.1 Technical lessons learned ............................................................... 86
  3.2.7.2 Socio-economic lessons learned .................................................. 89
  3.2.7.3 Institutional lessons learned ......................................................... 91
  3.2.7.4 Financial Lessons Learned ........................................................... 93
  3.2.7.5 Environmental lessons learned .................................................... 96
4. Financing .................................................................................................. 97
  4.1 Cost of Capital ................................................................................... 98
  4.2 Risk Mitigation .................................................................................. 99
  4.3 Renewables and Cost-Competitiveness .............................................. 105
    4.3.1 Considerations for Financing Renewable Energy in Remote Areas ... 105
    4.3.2 The Role of Government Subsidies ............................................... 105
    4.3.3 Capital availability and access ...................................................... 106
      4.3.3.1 Capital availability ............................................................... 106
      4.3.3.2 Access to capital ................................................................. 107
      4.3.3.3 International sources of funding .......................................... 109
        4.3.3.4 Public resources targeting capital availability, access AnD COST ... 110
    4.3.4 Innovative Business Models ......................................................... 110
      4.4.1 Energy performance contracting (EPC) .................................. 111
      4.4.2 Fee-for-service models ........................................................... 111
  4.5 Conclusion ......................................................................................... 112
5. Lessons Learned: Policy Challenges and Potential Solutions .............. 114
  5.1 Subsidies ......................................................................................... 114
  5.2. Training ......................................................................................... 115
    5.2.1 Technical assistance networks ................................................... 115
    5.2.2 Direct Training ............................................................................ 115
      5.2.2.1 Private Sector Led ............................................................... 115
5.2.2.2 Non-profit led ................................................................. 116
5.2.2.3 Government led ............................................................. 116
5.2.2.4 Utility led ........................................................................ 116
5.2.2.5 Academic institutions .................................................... 116
5.3 Planning ................................................................................. 117
5.4 Incentives and Financing ...................................................... 117
5.4.1 Incentive design ................................................................. 119
5.4.2 Additional support ............................................................ 120
5.4.3 Tax benefits ...................................................................... 120
5.4.4 Innovative tariff structures ................................................ 120
5.4.5 System planning ............................................................... 121
5.5 Scale .................................................................................. 121
5.5.1 Access to technology ......................................................... 121
5.5.2 Access to lower cost systems ............................................. 121
5.5.3 Access to financing ............................................................ 121
5.5.4 Access to alternative ownership structures ...................... 122
5.6 Research and Development ................................................... 122
5.7 Efficiency .......................................................................... 123
5.8 Level of Renewable Penetration ......................................... 124
5.9 Risk .................................................................................... 124
6. Conclusion ............................................................................ 126
6.1 Additional Research ............................................................ 127

Appendix A: Case Studies of Remote Areas .................................. 130
Kodiak, Alaska, USA ................................................................. 131
Lessons Learned ................................................................. 134
Ramea Island, Nfld, Canada ..................................................... 135
Lessons Learned ................................................................. 140
Faroe Islands, Denmark .......................................................... 141
Lessons Learned ................................................................. 145
Isle of Eigg, Scotland ............................................................... 146
Lessons Learned ................................................................. 150
Floreana Island, Glapagos, Ecuador ....................................... 151
Lessons Learned .......................................................................................................................... 154

Coral Bay, Western Australia ...................................................................................................... 156
Lessons Learned ......................................................................................................................... 159

Bonaire, Netherlands ................................................................................................................. 160
Lessons Learned ......................................................................................................................... 163

El Hierro, Canary Islands, Spain .................................................................................................. 164
Lessons Learned ......................................................................................................................... 168

Miyakojima, Japan ...................................................................................................................... 169
Lessons Learned ......................................................................................................................... 172

Reunion Island, France .............................................................................................................. 173
Lessons Learned ......................................................................................................................... 178

Scott Base & Mcmurdo station, Antarctica ................................................................................. 179
Lessons Learned ......................................................................................................................... 182

Akkan, Morocco ........................................................................................................................ 183
Lessons Learned ......................................................................................................................... 187

Case Study Interviews ............................................................................................................... 188

Appendix B: IEA-RETD Country Profiles .................................................................................. 189

Canada ........................................................................................................................................ 192
Overview of Remote Areas .......................................................................................................... 192
Current Energy Policy ................................................................................................................. 196
Relevant Projects ........................................................................................................................ 197
Additional Sources ..................................................................................................................... 197

Denmark ...................................................................................................................................... 198
Overview of Remote Areas .......................................................................................................... 198
Current Energy Policy ................................................................................................................. 198
Greenland .................................................................................................................................... 198
Faroe Islands ............................................................................................................................... 199
Relevant Projects ........................................................................................................................ 199
Greenland .................................................................................................................................... 199
Faroe Islands ............................................................................................................................... 199
Additional Sources ..................................................................................................................... 199

France .......................................................................................................................................... 200
Overview of Remote Areas ................................................................. 200
Current Energy Policy ........................................................................... 200
Relevant Projects .................................................................................... 201
Germany ................................................................................................. 202
Overview of Remote Areas ................................................................. 202
Current Energy Policy ........................................................................... 202
Relevant Projects .................................................................................... 202
Additional Sources .................................................................................. 202
Ireland ..................................................................................................... 203
Overview of Remote Areas ................................................................. 203
Current Energy Policy ........................................................................... 203
Relevant Projects .................................................................................... 203
Additional sources .................................................................................. 203
Japan ....................................................................................................... 204
Overview of Remote Areas ................................................................. 204
Current Energy Policy ........................................................................... 204
Relevant Projects .................................................................................... 204
Netherlands .............................................................................................. 205
Overview of Remote Areas ................................................................. 205
Current Energy Policy ........................................................................... 206
Relevant Projects .................................................................................... 206
Norway ..................................................................................................... 207
Overview of Remote Areas ................................................................. 207
Remote Research Stations ...................................................................... 208
Current Energy Policy ........................................................................... 208
Relevant Projects .................................................................................... 209
Additional Sources .................................................................................. 209
United Kingdom ...................................................................................... 210
Overview of Remote Areas ................................................................. 210
Scotland .................................................................................................. 210
Remote Research Stations ...................................................................... 212
Current Energy Policy ........................................................................... 212
EXECUTIVE SUMMARY

Remote areas around the world are at the forefront of the transition toward a more sustainable energy future. Faced with rising fuel prices, decreasing energy security, and widespread concern over global climate change, many remote communities are beginning to look to locally available renewable energy (RE) sources to provide solutions. Fortunately, renewable energy technologies (RETs) have never been better positioned to help address those challenges. As renewable energy costs come down worldwide, the economic, financial and ecological case for beginning to transition away from fossil fuels, and toward a greater reliance on more local and sustainable forms of energy is increasingly compelling.

While residents in remote communities are often sheltered from the full impact of escalating prices by subsidies of various forms, the evidence suggests that the true cost of providing fossil fuel-based energy services in remote areas is growing. The result is that in many remote areas, RETs can undercut, on a levelised basis, the cost of traditional sources such as diesel, providing valuable savings for governments, utilities and for ratepayers.

As a result, remote areas are becoming a topic of increasing international interest in the transition toward a more sustainable energy future. Many remote areas are located in pristine natural environments and are exposed to significant risks when diesel is transported along rudimentary roads with limited logistical support. From a technological perspective, remote communities also provide a test bed for the implementation of state-of-the-art technologies, including storage, grid integration, and the management of high penetration renewable energy systems. Moreover, deploying renewable energy technologies at scale in remote areas can provide many valuable lessons for central electric grids, as well as for mainland transportation and heating systems. Remote areas also provide promising locations to evaluate the economics of high-penetration scenarios, potentially shedding insights for larger countries with ambitious RE targets such as Germany, and Denmark.

The goal of this report is ultimately to provide decision-makers with a better grasp of the technical, economic and energy issues facing remote areas, as well as to provide a menu of policy options available to accelerate renewable energy development in these regions. In turn, the report aims to equip national, regional and local policymakers with perspective, context, and inspiration on how to develop sustainable energy strategies.

The report begins with a general introduction and a brief description of the core objectives of the study. The second part aims to provide a definition of “remoteness”, drawing on existing definitions used in regions such as the EU, Canada and Australia. The report draws a distinction between the causes of remoteness, which include being disconnected from central infrastructure, as well as the symptoms, and outlines three different ‘dimensions’ of energy remoteness: infrastructural, geographic, and economic. This report considers the most important factor in the definition of remoteness to be the lack of a direct connection to central infrastructure, such as pipelines and major electricity grids.

Providing energy services in remote areas can incur a tremendous cost, one that has traditionally been either borne or shared by central governments. Many remote areas, such as the French overseas
departments, do not pay the true costs of energy services, and are offered the same price as on the mainland. Energy subsidies of this sort encourage inefficient patterns of energy use, and represent a rising cost for many governments worldwide. To draw on one example, the government of Canada spent approximately $4,400 (CAD) per inhabitant of Nunavut in 2006 to supply fossil fuel-based energy services (including electricity, transport, and heating) to its communities. One of the key lessons of this report is that the targeted deployment of renewable energy systems, combined with improved energy efficiency, can significantly reduce the long-term costs of energy service in these communities. In addition, it can provide a set of non-monetary benefits such as improved environmental conditions, enhanced quality of service, greater energy security, and a host of other direct and indirect gains.

The third section of the report lays out a broad set of general and specific considerations applicable to remote areas. The general considerations are divided into the basic categories of energy use: heating and cooling, transportation, and electricity. This section provides a brief overview of the availability of renewable energy resources to supply these energy needs; it also includes a discussion of emerging technologies, such as hydrogen storage and electric vehicles, technologies that could come to play an important role in the years ahead.

In addition to general considerations, the report includes a more detailed set of specific considerations, which deal more narrowly with the climate and other factors that characterize different remote areas. This section established six broad categories of remote area,¹ which include 1) small areas with long winters, 2) areas with temperate climates, 3) small areas with warm climates, 4) large areas with warm climates, 5) remote research stations, and 6) remote areas in developing countries. Each specific category includes a detailed discussion of the environmental conditions unique to that category, an examination of the specific renewable energy sources available, and a high-level discussion of pathways to 100% renewable energy for each category of remote area.

<table>
<thead>
<tr>
<th>Remote Area Category</th>
<th>Case Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Remote Areas with Long Winters</td>
<td>Kodiak Island, Alaska, USA</td>
</tr>
<tr>
<td></td>
<td>Ramea Island, NFLD, Canada</td>
</tr>
<tr>
<td>Remote Areas with Temperate Climates</td>
<td>Faroe Islands, Denmark</td>
</tr>
<tr>
<td></td>
<td>Isle of Eigg, Scotland, UK</td>
</tr>
<tr>
<td>Small Remote Areas with Warm Climates</td>
<td>Floreana Island, Galapagos, Ecuador</td>
</tr>
<tr>
<td></td>
<td>Coral Bay, Western Australia</td>
</tr>
<tr>
<td>Large Remote Areas with Warm Climate</td>
<td>Bonaire, Netherlands</td>
</tr>
<tr>
<td></td>
<td>El Hierro, Canary Islands, Spain</td>
</tr>
<tr>
<td></td>
<td>Miyakojima, Japan</td>
</tr>
<tr>
<td></td>
<td>Reunion Island, France</td>
</tr>
<tr>
<td>Remote Research Stations &amp; National Parks</td>
<td>Scott Base &amp; McMurdo Station, Antarctica</td>
</tr>
<tr>
<td>Remote Areas in Developing Countries</td>
<td>Akkan, Morocco</td>
</tr>
</tbody>
</table>

¹ Note that these categories are not intended to be exhaustive, nor are they intended to reflect all types of remote area.
The fourth section of the report deals with financing projects in remote areas. Interviews with IEA-RETD country representatives indicate that most renewable energy projects to date have been either developed as pilot projects, for research and development (R&D) purposes, or have been financed with significant assistance from the central government. However, there is the possibility, with the rising cost of diesel and the declining costs of many renewable energy technologies, that some remote area projects could be financed on a stand-alone basis. Examples like the wind-diesel-hydrogen project on the island of Ramea in Canada have demonstrated that with an appropriate institutional environment, innovative power purchase agreements and targeted support from different levels of government, projects can be successful in attracting investment. Building on cases like these could help make remote area financing partnerships more common, while making them replicable across a wider range of institutional, cultural, and socio-economic settings.

In addition, the financing section provides a look at how issues like the cost of capital can impact the cost-competitiveness of renewable energy technologies. It also examines related issues such as the availability of capital, the unique risks that characterize remote area projects, as well as some of the barriers that may be holding certain projects back. Despite the fact that there is a strong, prima facie case for deploying renewable energy in remote areas, many economic and non-economic barriers often prevent financing from occurring in a broad-based and scalable manner. Consideration is also given to the role of government subsidies, which have historically been the primary funds supporting projects in remote areas. The bulk of these subsidies currently focus on subsidizing the bulk purchase, delivery, storage, and/or the final retail cost of diesel or other fossil fuels. In some cases, where governments are seeking to encourage private sources of financing to enter the market, it may be necessary to gradually ramp down such subsidies to conventional energy sources in order to attract both alternative sources of financing, as well as alternative energy technologies. In certain areas, the continued subsidization of fossil energy sources represents one of the primary barriers to the wider adoption of renewable energy technologies.

The report also examines the potential for international sources of funding such as the Clean Development Mechanism (CDM) as well as the use of carbon funding. However, it concludes that the ability of remote areas to tap into these sources of international funding is limited, due in part to scale, and to lack of institutional support. As a result, there is a possibility to adopt innovative business models such as pay-for-service, performance contracts or ‘energy service company’ (ESCO) models, as well as different ownership structures. Indeed, the country-specific case studies feature a wide range of different ownership models, including government-owned, utility-owned, and community-based or cooperative models. Such innovative business models may be able to open new avenues for funding, and provide a greater degree of flexibility to adapt to local contexts, and better manage risk. Ultimately, financing renewable energy projects in remote areas requires a greater degree of context sensitivity, a more careful consideration of logistical and operational requirements, as well as broader cooperation between all participants involved, particularly with the communities in which such projects are located.
Finally, the report includes a detailed set of case studies drawn from a number of IEA and non-IEA countries. These case studies discuss the technical, financial, regulatory, ownership and other considerations unique to each project, and provide a glimpse into the cost savings they offered (where applicable), as well as the challenges many of them faced to get off the ground. **These case studies also provide valuable lessons for jurisdictions seeking to increase the use of renewable energy in remote areas, and some of the challenges that may need to be overcome before high levels of RE penetration can be reached.** Among others, these lessons include the importance of collaboration between local residents, utilities, government, and the private sector; the need for developing local expertise and technical capacity; the importance of designing appropriate institutional and policy supports; the potential for RETs to reduce the costs of energy service and improve reliability; and the importance of engaging local citizens in the development and implementation of energy strategies.

The case studies provide a number of lessons learned that could be applied at the community, provincial and even national levels. The report summarizes the implications of these lessons learned and discusses several ways in which governments at all levels can help overcome some of the challenges facing the deployment of RETs in remote areas:

1. Scaling back **fossil fuel subsidies**;
2. Assisting with **training and the lack of technical expertise**;
3. Assisting with **project planning and implementation**;
4. Designing **appropriate incentives**;
5. Overcoming the issue of **scale**;
6. Increasing **research and development (R&D)** funding;
7. Prioritizing **energy efficiency**;
8. Determining the **appropriate level of RE penetration**;
9. **Mitigating risks**

In addition to this report, a study of the remote areas in the 9 IEA-RETD countries and the energy policies that support these areas is available as a separate document.

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. Finally, the lessons learned from transitioning remote areas to higher levels of renewable energy penetration can help mainland areas better understand the technical, financial, operational challenges and can help them harness a greater share of their locally available energy resources as well.
1. INTRODUCTION

Remote areas and islands are under stress as a result of their dependence on petroleum, currently the most expensive and least secure fossil fuel. With a few exceptions, the majority of the world’s remote areas depend on oil for all of their electricity, heating and cooling, as well as their transportation needs. Moreover, the transportation systems that serve as lifelines to these areas are also dependent on petroleum. The economies of remote areas and islands are therefore extremely vulnerable to rising oil prices, oil price volatility, and supply disruptions. Remote areas are also under stress as a result of environmental challenges such as climate change and the adverse impacts of fossil fuel transport (e.g. oil spills).

As IEA-RETD countries implement aggressive national renewable energy policies, their continental-scale energy systems will eventually confront the integration challenges that some remote islands and areas are already beginning to face. Germany’s target of 80% renewable electricity by 2050, for example, will no doubt require the utilization of innovative storage, efficiency, and integration strategies that jurisdictions like Hawaii are deploying right now.

This report primarily examines renewable energy in the remote areas islands of the IEA-RETD member countries: Canada, Denmark, France, Germany, Ireland, Japan, the Netherlands, Norway, and the United Kingdom. The lessons garnered from this exercise could be readily applied to remote areas in other developed countries. Although the policy and technological solutions for remote areas in developing countries vary from those in developed countries, there are also clear lessons learned that can be applied in both directions. As many of the case studies demonstrate, remote regions provide a valuable testing ground for the implementation of high penetration RE scenarios, as well as for the real-world deployment of innovative storage and demand side technologies.
2. DEFINING REMOTE AREAS

2.1 RECOMMENDED DEFINITION FOR THE REMOTE PROJECT

The goal of this section is to identify a useful definition of “remoteness” in order to support renewable energy policy development for remote communities. Although the search for a comprehensive definition of what “remote” means can be a lengthy and highly academic process, the goal of this exercise is to develop a practical definition that policymakers can use as a point of reference.

From the perspective of energy policy development, we define energy “remoteness” both by its causes and by its symptoms.

**Causes:** A community is considered “remote” if it is not connected to central energy infrastructure – either a national electricity grid or a natural gas pipeline. This lack of connection to central distribution infrastructure is the threshold condition for whether a community is considered remote or not. While a lack of connection to road networks or maritime infrastructure (e.g. ports) may exacerbate remoteness, it is less significant from an energy policy perspective than the lack of connection to central infrastructure.

**Symptoms:** A lack of connection to central energy infrastructure means that the community will need to rely on liquid fuels – whether they are delivered by land, sea, or air – to supply all of its energy services unless it can identify and exploit local energy resources. Liquid fuels create significant economic, environmental, and social costs, as well as perpetuate a deeper dependency on imported energy. For all of these reasons, the reduction (and eventual elimination) of the reliance on liquid fuels is correctly the focus for IEA-RETD’s renewable energy policy efforts for remote communities. A second symptom of energy remoteness is lower quality energy supply, which can manifest itself in the form of low reliability (e.g. a weak grid) and/or frequent energy supply disruptions (e.g. a delay or cessation of liquid fuel deliveries). Finally, a third symptom of energy remoteness is that remote areas tend, on average, to face higher cost energy. These higher costs are generated through a combination of factors, including generator inefficiency, the fuel delivery premium, and the high cost of the primary fuel itself.

As will be explored throughout this report, this definition encompasses a broad range of areas, ranging from remote mainland fishing communities in the Arctic to tourist destinations in the Caribbean. Although remote areas are united by the common challenges of securing affordable and reliable energy, different types of remote areas will require different energy policy approaches and renewable energy technology solutions. The distinctions between different remote areas are explored in Section 3.2.

The remainder of this section presents additional considerations for defining remote areas from an energy policy perspective, including the relationship between different definitions of remote, the distinctions between remote areas in developed and developing countries, and the definitions of “central” and “weak” grids.
2.2 ADDITIONAL CONSIDERATIONS

2.2.1 THE RELATIONSHIP BETWEEN DIFFERENT DEFINITIONS OF REMOTE

A survey of international government programs reveals that different policymakers use different frameworks for categorizing remote areas. These different approaches point to three different ‘dimensions’ of remoteness:

- **Infrastructural.** Infrastructural approaches define remoteness according to whether or not an area is connected to central infrastructure. Natural Resources Canada, for example, defines remote areas as those that are “Not presently connected to the North-American electrical grid or piped natural gas network” (RETScreen International, 1998; Sigma Engineering, 1985). As described in the section above, this report adopts an infrastructural approach, and makes the lack of connection to central infrastructure the primary cause of remoteness.

- **Geographic.** Geographic approaches classify remote areas based on their distance from anchor points such as major population centers (Gallego, 2004) or on related indicators such as population density. In a study by Nordregio, for example, remote areas are defined as those in which less than 10,000 people live within a 50 km. sq. radius and may lack access to “threshold daily services” (Gløersen et al., 2005).

- **Economic.** Economic approaches classify remote areas as those where individuals cannot afford access to basic energy services.² In this context, the economic inability to secure energy services is understood as another ‘dimension’ of energy remoteness.

These three approaches are distinct; they also exhibit clear interrelationships when viewed from the perspective of energy policy (see Figure 1). Although this report uses an infrastructural definition, it is useful to consider the areas of overlap between these different concepts of remoteness and the implications that these may have for energy policy. Rural areas such as those in sub-Saharan Africa, for instance, can be remote in every sense (i.e. economically, infrastructurally, and geographically) and will likely require different renewable energy policy approaches from areas such as Kuau in Hawaii, which may be geographically and infrastructurally isolated but economically well-positioned.

---

² Economic approaches are related to socio-economic approaches which “concentrate on how perceptual, behavioral and socio-economic characteristics of inhabitants of an area impinge upon accessibility to services.” (Information and Research Branch, 2001)
2.2.2 DISTINGUISHING BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

The primary focus of this report is on remote areas in IEA-RETD and other developed countries. There are many areas in developing countries, however, that also qualify as “remote” communities from the perspective of access to energy infrastructure. Remote areas in developed and developing countries face many of the same challenges; as a result, there are many lessons and experiences that can be shared in both directions. Several of the case studies contained in Appendix A draw explicitly on lessons from remote renewable energy installations in developing countries. At the same time, there are distinct differences between developed and developing countries that may have important implications for policymakers. This section provides a high-level overview of some of these differences:

- **Energy access**: In developed countries, a key policy challenge for remote communities is how to displace fossil fuels in the generation mix. In many developing countries, by contrast, a key challenge is establishing energy access in the first place. Approximately 3 billion people globally rely on traditional fuels for cooking and 1.5 billion lack access to electricity (Legros et al., 2009). Energy access can be driven by infrastructure and geographic considerations. For example, there is only a 21% electrification rate across the Least Developed Countries (LDCs), with most electrified areas concentrated in urban centers. However, energy access in developing countries can also be purely an economic issue and therefore a question of poverty alleviation rather than energy service.
availability. This is the case, for example, for many residents of the Kibera slum in Nairobi and the Favelas in Brazil where energy may be available in theory, but unaffordable in practice. Policies to support energy access in developing countries may include focus areas that are less relevant in developed countries, such as a heavy focus on microfinance or on the provision of low-emissions fossil fuel sources for cleaner cooking.

• **Economic resources.** As indicated from the Project Team’s baseline survey of remote areas in IEA-RETD countries (Country Profiles Addendum), developed countries heavily subsidize energy from both fossil fuel and renewable sources in remote areas. For instance in 2007, the Territory of Nunavut in Canada, as the bulk purchaser of fuel for its communities, spent approximately $130 Million CAD (€99 Million) to supply its citizens with energy services. This was split relatively evenly between electricity (27%), heating (33%), and transportation (40%) (Energy Secretariat, 2007). With a population of 29,474 at the time, this works out to $4,410 CAD (€3350) per inhabitant, and represents almost 20% of the Territory’s annual budget. What is remarkable is that at the time, diesel fuel was priced at $0.79 CAD/Liter (€0.60/Liter) – current costs are roughly double, or approximately $1.50 CAD/Liter (€1.15/Liter). Although a growing number of developing countries are introducing innovative policies to support both energy access and increased renewable energy deployment in remote areas, their ability to bring these policy solutions to scale is limited by their ability to absorb the policy costs. Ratepayer surcharges to support renewable energy are politically sensitive in all areas of the world, but residents of developing countries are less able to afford them than their developed world counterparts because basic commodities account for a larger percentage their household incomes (IMF, 2011). The range of policy incentives and policy interventions that developed countries can consider may be broader than what is available to developing countries given the disparity in resources.

• **Electricity market structure.** Over the past few decades, groups such as the World Bank have supported a “standard model” for power sector reform, where countries unbundle or privatize their utilities or “liberalize” their electricity markets. This has caused widespread liberalization in developing countries (Gratwick et al., 2006), although notably some countries have reverted to a public utility after a trial with privatized markets (e.g. Ecuador). Meanwhile some countries have opted to maintain their state-run monopolies (e.g. Costa Rica, France). Within the set of countries that have introduced power markets, some have also adopted full retail electricity competition (Besant-Jones, 2006). Many of the IEA-RETD countries have undertaken these significant power sector transitions and introduced retail electricity competition. Electricity market and utility structures can significantly influence the feasibility of different policy approaches to support renewable energy in remote areas. As a result, some potential policy options that may work well in liberalized electricity markets may not be directly applicable to monopoly utilities and vice-versa.

---

3 More than half the countries in the world with renewable energy targets, for example, are developing countries (REN21, 2011), and Peru, Tanzania, and Ecuador are the first countries to introduce feed-in tariffs for off-grid installations (Rickerson et al., 2010a; Rickerson et al., 2010b)
2.2.3 DEFINING “CENTRAL” GRIDS AND “WEAK” GRIDS.

There are two additional sets of considerations that are relevant to the definition of energy remoteness but which are not central to the definition utilized in this report. These include the technical definitions of what constitutes a “central” infrastructure and what constitutes a “weak” grid connection.

- **Central grids.** Remote communities are defined as those not connected to central infrastructure. The term “central” however, is relative and is interpreted differently by different policymakers. Canada defines the areas where electricity is delivered in areas governed by the North American Reliability Council (NERC) as the “central” grid. By this definition, regional grids outside of NERC, such as those that serve Yellowknife and Whitehorse, are classified as remote. In Japan, the 400+ inhabited islands aside from the five mainland islands are considered remote. In other countries, however, central infrastructure may not be as clearly or neatly delineated. This raises questions as to when a “central” grid ends and a “remote” grid begins. Such distinctions, however, were beyond the scope of this report.

- **Weak grids.** Another concern with using the term “central infrastructure” is that it does not include explicit consideration of infrastructure that is too small, unstable and/or old to provide reliable energy services. This could include, for example, near-shore islands with a connection to the mainland that is not sufficient to meet island demand and creates reliability concerns. It may also be possible to create a technical definition of “remoteness” that explicitly references power standards. Such an effort was beyond the scope of this report, but a primer on power quality measures (e.g. reliability, voltage, frequency, power factor, waveform distortions, etc.) was prepared to as a background document for this project. This primer is included as Appendix B. As with the definition of “central” infrastructure, a technical definition of what constitutes a “weak” grid could be useful to compare the energy policy needs of weak grids with those of “remote” communities.

The remainder of this report is written with the assumption that the definition provided in Section 2.1 is a practical and useful starting point for IEA-RETD policymakers, but acknowledges the potential to expand the definition or energy remoteness to be more nuanced and complex.
3. RENEWABLE ENERGY CONSIDERATIONS FOR REMOTE AREAS

This section explores the factors that influence renewable energy technology (RET) development in remote communities. The section first outlines general considerations for renewable development that may be broadly applicable to all remote areas. The following section then introduces a methodology for categorizing specific types of remote areas and identifies the challenges and opportunities related to renewable energy deployment in each one. Each of the specific categories is supported by representative case studies (Appendix A) that highlight real-world experience with renewable energy development and lessons learned. This effort draws on related attempts to characterize renewable energy in remote areas such as the European Insular Area Typology (Technical University of Crete, 2006) and efforts to catalogue renewable energy on islands (Jensen, 1998, 2000), but focuses primarily on conditions in remote areas that have implications for energy policy.

3.1 GENERAL CONSIDERATIONS

Conditions in remote areas vary widely from one area to the next, with different climates, economies, energy resource availability, political and institutional contexts, and cultures. This section provides a high-level overview of the factors that may impact renewable energy development across a spectrum of remote areas. This section focuses on technical considerations related to high-level penetrations of renewable energy in the electricity, heating and transport sectors of remote areas; the competitive position of renewable energy; and socio-economic considerations that have implications for renewable energy development.

3.1.1 THE COST OF RENEWABLE ENERGY

Renewable energy technologies have become competitive with conventional resources in many areas of the world, most notably in remote areas, over the last five to ten years. This is primarily attributable to two key factors: the rising cost of diesel generation, and the rapidly declining cost of renewable energy technologies. This subsection briefly examines both.

3.1.1.1 THE RISING COST OF DIESEL

As discussed in Section 2, dependence on diesel fuel is one of the defining characteristics of remote areas. On an unsubsidized basis, renewable energy is now broadly competitive with electricity from diesel generators at today’s fuel prices. During the past several years, oil prices have achieved historic highs, peaking at $147/barrel (€112/barrel) in July, 2008, and averaging over $100/barrel during 2011. These increases in oil price have caused the price of diesel generation to more than double in the last decade. At current oil prices, diesel generation is significantly higher on a $/kWh basis than all renewable thermal applications and higher than almost all power generation technologies (depending on location and application) (REN21, 2011; Syngellakis, 2011). This trend has dramatically expanded the portfolio of diesel energy alternatives for renewable energy transition, particularly when coupled with the fact that renewable energy technologies have come down rapidly in cost. Recent evidence from
India, for example, suggests that solar PV is already significantly cheaper than diesel in many areas, prompting major industrial customers to begin increasing their use of solar in off-grid applications (Pearson, 2012). These trends are relatively recent, however, and policymakers have an opportunity to consider new strategies for unlocking the potential of renewable energy in remote communities.

- **Declining renewable energy costs.** Solar photovoltaics represent the most dramatic illustration of renewable energy cost declines and the potential for renewables to compete with diesel. PV panel prices, for example, declined by 40% in 2009/2010, and are projected to continue to decline significantly in 2011/2012 (Wienkes et al., 2011). This drop in panel prices has brought unsubsidized PV into competitive position with electricity generated from large diesel generators (as can be seen in the graph below). For smaller diesel gensets, solar PV is already cheaper on a levelised basis. The graph below depicts the delivered or ‘busbar’ price of electricity and does not reflect the impact of storage or other grid integration costs on LCOE. This demonstrates that a remote grid that uses diesel generators for all electricity needs would be able to reduce costs by adding in low-penetrations of PV. At higher penetrations of renewables, storage becomes necessary. A discussion of the interaction between storage and LCOE is contained in Text Box 1.

![Figure 2: Levelised Cost of Energy (LCOE) Trends for Diesel Energy and Solar PV. Source: HOMER](image-url)

Figure 2: Levelised Cost of Energy (LCOE) Trends for Diesel Energy and Solar PV. Source: HOMER
The competitive position of renewable energy can provide additional economic benefits to local communities and utilities beyond direct savings. Renewable energy sources such as wind, solar, and geothermal have no fuel costs and are therefore able to sell energy at stable and predictable prices for the life of the project. This long-time stability creates a hedge benefit for communities and also reduces exposure to the volatility of diesel prices. However, context is essential. Off-grid, pico-scale PV (e.g. 100W or smaller), for example, could have a much higher levelised cost of energy than a large diesel generator in an urban area, even with the rising cost of diesel fuel. This notwithstanding, the cost of diesel in remote areas could be significantly higher than depicted in the graph above (Syngellakis, 2011).

Moreover, the hedge created by renewable energy can be more secure and complete than financial hedges linked directly to fossil fuel prices, such as swaps, futures or fuel purchase contracts (Bolinger et al., 2004).
To build on this analysis, the following two graphs provide an indicative comparison of wind, solar and diesel system costs over a fifteen (15) year timeframe, deployed at a small scale to supply electricity in a remote area. The first graph compares the economic performance of the different technologies with diesel at US$1.50/liter (€1.15/liter), while the second compares them at US$2.00/liter (€1.53/liter).

The first graph compares the economic performance of the different technologies with diesel at US$1.50/liter (€1.15/liter), while the second compares them at US$2.00/liter (€1.53/liter).

Figure 3: Diesel, Solar, and Wind 15 Year Cost Projections when Diesel = $1.50L (€1.15/liter). Source: Own elaboration

These two comparisons include the following assumptions: the daily electricity demand is 360kWh of electricity. This assumes diesel operation for eight hours per day, a wind capacity factor of 20%, and a solar capacity factor of 15%. Solar costs are assumed to be $3.50/W installed; micro-wind is assumed to be $5.50/W installed; and the diesel genset is priced at $18,000 USD, or $0.40/W. It does not include the cost of storage, and assumes that electricity is fed into a small grid, or consumed as available. Operations and maintenance (O&M) costs are assumed to be roughly 0.3% of total capex for solar PV, and 1.14% of capex for wind power. Diesel is priced at $1.50/L and $2.00/L and assumed to remain constant for fifteen years.
As these two charts demonstrate, while diesel generators are significantly less expensive to purchase (by a factor of approximately 20), their high operating costs make them approximately twice as expensive to use to supply remote electricity over a 15-year timeframe. Also, the cost of renewable energy technologies continues to come down globally, which suggests that the comparative economics are likely to get better than the above projections in the years ahead.

Naturally, the business case for renewable energy is not as straightforward as this depiction suggests; many investments such as these simply fail to be adopted by the market due to a number of market failures and other barriers. The long-standing argument has been that once RE technologies reach “grid parity”, the market will respond, and renewables will begin to replace fossil generation (and diesel in particular) automatically. However, evidence suggests that this has not occurred on the scale conventional economic theory would predict, even in remote areas where renewables have already reached or surpassed grid parity. Although this is attributable in part to the non-economic barriers described in Section 3.2, it is also attributable to several financial challenges. The latter include the role of subsidies (conventional diesel-based generation is often subsidized at many levels, including delivery, storage infrastructure, bulk purchasing, and direct price subsidies for retail customers, etc.), availability...
of capital (investors are generally less interested in remote areas), access to capital (projects cannot gain access to available capital), and the cost of capital (i.e. high interest rates). See Section 4 for more details on financing projects in remote areas.

In addition to these economic arguments, there are also significant environmental and social arguments for integrating renewable energy into remote areas. Remote areas, for example, are on the “front lines” of climate change, with many areas already experiencing impacts such as melting permafrost and rising sea levels. As a result, some remote areas are prioritizing low-carbon development, with an emphasis on renewable energy development. The Republic of the Maldives, for example, is a low-lying country in the Indian Ocean that is at risk of inundation as sea levels rise. Recently, the Maldives (2010) submitted to the United Nations that its nationally appropriate mitigation actions would focus on achieving carbon neutrality as a country by 2020.

Taken together, these challenges mean that despite the strong, prima facie case for deploying renewables in remote areas, many economic and non-economic barriers remain for renewable energy financing to occur in a consistent, scalable manner.

Despite the favorable trends now characterizing RE technologies (rapidly declining costs, low variable costs, etc.), challenges to deployment in remote areas remain. Chief among these is the high upfront cost of renewables and the ability of remote communities to secure financing. The high costs of O&M and difficulty securing spare parts in remote areas is also a barrier. These topics are discussed in greater detail in the sections below.

3.1.2 ECONOMIC RESOURCES AND ACTIVITY

The economies of remote areas vary widely. Their primary activities range from tourism and agriculture in warmer regions such as the Caribbean to fishing in northern islands such as St. Pierre and Miquelon, to resource extraction (e.g. diamonds in Yellowknife, Canada). Although it is difficult to generalize about the economies of remote areas globally, two factors have important implications for renewable energy.

• First, the economies of many remote areas are not diversified, which makes them vulnerable to shifts in key industries or commodities. The economy of St. Pierre and Miquelon, for example, was historically dependent on fishing and suffered when overfishing and restrictions on fishing in Canadian territorial waters caused the fishing industry to sharply contract. Similarly, tourism accounts for the majority of exports in most Small Island States and tourism contracted sharply during the recent financial crisis (UN DESA, 2010).

• Second, the cost of living in many remote areas is comparatively high (UN DESA, 2010). Even if a remote area has a higher per capita income than a non-remote area in the same country, it is possible that the remote population will be comparatively poor because of the higher costs of consumer goods and commodities (such as energy).

The primary implications of these factors for energy planning is that remote communities may have lower purchasing power and access to capital in general, and particularly during economic downturns. This may prevent remote communities from being able to finance renewable energy investments even
when renewables are competitive with fossil fuels on a lifecycle basis. A second implication is that economic vulnerability can result in significant swings in economic activity and, as a result, potentially large changes in demand for energy. Changing load, particularly for small communities (e.g. the island of Saba only has ~2000 people) can complicate energy planning in general and renewable energy planning specifically.

### 3.1.3 DEMOGRAPHIC TRENDS: POPULATION GROWTH, MIGRATION AND EMIGRATION

Population trends can have important implications for energy planning. Although each remote community faces its own demographic trends, broad demographic considerations for policymakers include:

- **Birth rates.** Some remote areas, such as small island developing states (SIDS) in the Pacific, are experiencing significant increases in population growth because of higher birth rates (Connell, 2003). Others, such as the remote areas in Japan are experiencing low birth rates and population declines that mirror broader nationwide trends (Horlacher and MacKellar, 2003).

- **Migration.** Migration within remote areas has broadly involved a shift of population from peripheral areas to more populous centres with greater availability and quality of services and/or employment opportunities. In many SIDS nations, for example, this has involved a shift in populations to “main” islands and from rural areas to urban coastal centres. The total urbanization of SIDS has increased from 49.5% in 1990 to 55% in 2008 (UN DESA, 2010).

- **Emigration.** Emigration is defined here to mean the movement of people away from remote areas to non-remote areas. Although the overall population of some remote areas is stable and growing, some remote areas have experienced significant emigration. Cape Verde, for example, has a current population of ~500,000, but it is estimated that close to 1 million people have emigrated (Vilar, 2011). A related challenge is that emigration often occurs disproportionately among skilled workers, which creates a “brain drain” on local communities. During the decade from 1966-1976 and again in the 1990s, for example, it is estimated that more than half of the vocationally qualified workers moved away from the Cook Islands to seek employment opportunities abroad (Connell, 2003).

Given these population shifts, energy planners and renewable energy planners face a dual challenge. On the one hand, there is a significant opportunity to plan to meet increased energy demand in growing areas such as cities using renewable resources. Technologies such as solar electricity and water heating technologies, for example, can be seamlessly integrated into the urban environment and into new construction. On the other hand, regions with falling populations may be left with declining demand and oversized energy systems which may create challenges for renewable integration. Policymakers should keep population trends in mind as they design renewable energy policy infrastructure.

It is also important for policymakers to consider that renewable energy development may also have an impact on the population trends of small remote areas. As discussed below, renewable energy may create new economic opportunities for local residents. Economics are not the only driver for migration or emigration, however. Population movement is also influenced by access to quality services, improved
standards of living, and good working conditions. Renewable energy can improve power reliability, ensure year-round energy security (i.e. bridge diesel supply disruptions), benefit the local environment, and build a sense of community ownership. Renewable energy can also reduce the “nuisance factor” of diesel supply. In remote communities where diesel is delivered by sea or air, for example, residents may lose one more days of work to the task of unloading and transporting fuel to their homes and/or places of business. These and other benefits are less easy to monetize but may contribute to improvements in perceived quality of life and reduce incentives for migration.

3.1.4 AVAILABILITY OF TRAINED TECHNICIANS

In some cases such as solar PV, renewable energy systems are easier to maintain and operate in terms of both time and effort than diesel generator sets. However, RETs can require more specialised technical knowledge for installation and maintenance services. A major challenge, however, is the availability of trained maintenance technicians. Renewable energy can create new job opportunities in remote areas. In some cases, however, there has been a gap between the potential for jobs and the ability to fill them locally. Given the geographic isolation of remote areas and the comparatively small size of many renewable energy systems in remote areas, it can be challenging for project developers to create capacity building and training programs in a cost-effective manner as part of project development. Moreover, local government and utilities may not have the resources or the expertise to organize training programs. Capacity building is therefore a critical need which can “fall through the cracks” in remote areas without attention of entities with sufficient resources to provide it (e.g. national governments). This problem can also be compounded by the emigration of trained technicians discussed above, as well as the logistical challenges of sourcing spare parts described below.

3.1.5 LOGISTICS

Logistics in remote areas are inherently difficult. Many remote arctic communities, for example, are not served by roads and their primary modes of supply and trade are through sea and air links -- extreme winter weather can disrupt both air and sea transport. Even in areas with comparatively mild weather, however, logistics can present a barrier to basic commerce and specifically to renewable energy development. The World Bank Logistics Performance Index ranks nations according to how well they perform in terms of transport costs, quality of roads and ports, tracking of shipments, and on-time delivery. Almost all of the SIDS tracked by the index rank comparatively low, with island nations such as Fiji and Cuba among the lowest performers in the world. The challenges of logistics in remote areas can complicate and constrain both renewable energy installation and operations and maintenance. Renewable energy technologies such as wind and solar do not require regular fuel deliveries like diesel does. Some technologies, however, require special equipment to build which may not be available in remote areas. Many remote areas lack both the handling equipment and cranes necessary to erect megawatt-scale wind turbines, for example. In such circumstances, remote areas may need to opt for several smaller units (e.g. 100kW turbines) to install their required capacity. Also, they may opt to install refurbished or recycled turbines, as older mainland sites are repowered with larger, more efficient

---

turbine models as has occurred on Ramea island in Canada. This may create additional O&M and logistical challenges by increasing the frequency of technical service requirements.

A more critical issue is the availability of spare parts. The proper operation and maintenance of renewable energy systems over time is a significant barrier to renewable energy development in remote areas. Historically, many RET systems installed in remote areas in both developed and developing countries have failed early because they were not properly maintained. This is partially related to a lack of trained technicians (see above) but also related to the availability of spare parts. Given the challenging logistics of remote areas, policymakers may need to consider equipment standards that require robust and simple systems that with an accessible supply of parts. Alternatively, encouraging the manufacturers of RE systems in remote areas can help improve the availability of parts. This has been achieved in the French island of Reunion, where over 70% of the components of solar hot water systems are produced locally.

In both cases, getting access to either trained technicians or spare parts in remote areas generates a set of challenges, as both often have to be flown in. This can and often does lead to significant delays, and higher project costs. While local manufacturing can mitigate some of these issues, it is likely that certain components will almost always have to be imported.

### 3.1.6 Economic Development Benefits

The job creation potential of renewable energy has been documented extensively in a range of national and international reports (Kammen et al., 2004; Renner et al., 2008). Renewable energy can have a direct job impact in local communities for both construction and on-going operations and maintenance jobs. Renewable energy installations can also have indirect impacts on upstream jobs (e.g. increased manufacturing and assembly jobs) and induced impacts through the expenditures made by those with new jobs. Renewable energy can also provide additional revenues for remote area governments to the extent that the governments assess sales tax, property tax, import duties on renewable energy equipment and/or income taxes on renewable energy system revenues. Finally, renewable energy can provide economic benefits to system investors. Systems that are partially or wholly owned by remote communities or their members, for example, will ensure that project revenues cycle back into the local economy (Houghton, 2010; Lantz and Tegen, 2009). A 2MW wind project could generate $500,000 (€382,000) in additional economic output impacts for the local community if it was 100% locally owned (instead of entirely owned by offshore investors).

Indeed, several of the communities profiled in this report have realized significant economic development benefits. The Isle of Eigg’s renewable energy cooperative, for example, created five new jobs in a community of 96 residents, whereas the island of Unst in the UK created (pop. 806) created 10 new jobs through its recent wind and hydrogen project (SMALLEST, 2008). The improvement in power

---

7 This calculation was conducted using the US National Renewable Energy Laboratory’s Jobs and Economic Development Impact model for wind. It assumed a 2 MW system sited in Alaska with an installed cost of $3.50/watt. The model assumed a 70/30 debt to equity ratio, an interest rate of 10% and a return on equity of 16%. The local share of all inputs was assumed in the base case to be zero. The model was then adjusted to reflect 100% local debt and equity in order to compute the results.
availability and reliability can also unlock new economic opportunities. In the case of Floreana in the Galapagos Islands for example (Appendix A), the improvement in power service availability permitted the installation of egg incubation for chicken farmers. The wind-diesel-hydrogen hybrid system on the island of Ramea has provided valuable savings to the local utility involved by reducing annual diesel expenditures. These economic development benefits may create new opportunities in remote areas that are otherwise experiencing significant emigration.

At the same time that renewable energy can create economic benefits, it is important to realize that renewable energy can decrease jobs to the extent that it displaces fossil fuels. The industry that supports local diesel transportation, storage, distribution and sales infrastructure in remote areas can be an important employer. Some stakeholders may perceive renewable energy systems that replace this infrastructure as a threat to the local economy.

3.1.7 COMMUNITY ACCEPTANCE

The issue of community acceptance of renewable energy has been well documented in many studies during the past two decades, including in the recent IEA-RETD RENBAR report (IEA-RETD, 2011). Renewable energy siting has often caused controversy in both non-remote and remote communities for a range of aesthetic, environmental, and cultural reasons. In Hawaii, for example, geothermal power was challenged in federal court by community members who charged that it interfered with worship of the volcano Goddess Pele (Boyd, 2002). Both policymakers and project developers need to carefully consider how new renewable energy systems will be received by local communities and structure appropriate community engagement.

Renewable energy need not always pose an aesthetic or cultural problem, however. As discussed above, many remote areas in warmer climates (e.g. SIDS) are destinations for tourists that are attracted to the natural environment. For both these “natural tourists” and for eco-tourists who are more specifically motivated by environmental sustainability, renewable energy installations can be an effective component of brand building and brand management to support the tourism industry (Daly et al., 2010). Community ownership of renewable energy systems can also create both literal and figurative buy-in and reduce siting concerns. This can be seen in the case of Samsø, which has developed both onshore and offshore wind projects as well as biomass district heating systems in a community-based way, drawing on local sources of financing (see Text Box 2 below). Not only does this help increase community support, it can also help create a shared vision for the future of the area, and a stronger spirit of civic engagement and participation.

Socio-cultural issues are of higher relevance when developing a project in remote areas, particularly in indigenous and small communities. For example, the Electricity Sector Council in Canada has recommended a national policy promoting aboriginal inclusiveness in the renewable energy and electricity sector for remote areas (Electricity Sector Council, 2009). Adequate and transparent information dissemination plus a partnered approach (community + developer) has been successfully used (see Akkan, Eigg, and Floreana case studies in the Annex), especially when establishing a model to manage and operate systems. This can be accomplished with clear tariffing structures, providing clear system capability to promote clear understanding within the community, and ensuring long-term
sustainability of projects. Buy-in from community, local authorities and other actors is essential. Energy projects that have a high probability of uncovering important archeologically resources should include protocols for archaeological assessment. For example, Ontario mandates this as part of the Renewable Energy Approval Process of the Green Energy Act, 2009 (Ontario Ministry of the Environment, 2011).

Text Box 2: The Island of Samsø, Denmark

The island of Samsø in Denmark has garnered attention worldwide for its ambitious plans to be supplied 100% by renewable energy sources, a goal it set in 1998, and which it has now effectively achieved. Over 70% of local heating needs are supplied with a district heating system, and when the wind is particularly strong, it exports the excess wind generated electricity via an undersea cable to the Jutland peninsula of Denmark, approximately 15 km away. As a result of this infrastructural link, Samsø is not a truly “remote” area in the sense established in the above definition (see Section 2.2.1), but it provides an interesting example of an island that has rekindled the notion of self-sufficiency and shown that with the right support from local residents and the government, even the most ambitious goals can be achieved.

With a population of just over 4,000, and a total size of 112 km², Samsø has built its approach around a community-based model of renewable energy development. The wind projects on the island have been partly financed by issuing shares to allow local residents and Danish citizens to invest directly in the project. This includes both an onshore as well as an offshore wind project. In addition, to supply the island’s heating needs, local residents have developed two district heating systems that make use of waste biomass resources such as straw and wood to heat water, which is then circulated throughout the community.

3.1.8 ENVIRONMENTAL CONSIDERATIONS

Proper consideration of environmental factors is vital to the success and sustainability of RET in remote areas; they tend to be less developed and are more likely to have fragile and less diverse ecosystems that in many cases have been comparatively less disturbed by human habitation.

- **Remote areas are often in highly sensitive environments**: Given the isolation of many remote areas they tend to have sensitive and fragile ecosystems environments. Many remote areas are located in sensitive and unique biosystems that require special consideration (e.g. protected biodiversity). Although renewable energy technologies can have a lower environmental impact than diesel, they can still disturb or negatively impact the environment (Bickel et al., 2003). Site-specific environmental due diligence needs to be performed for each system, acknowledging that different technologies may pose different risks. Many of the environmental concerns are now common knowledge thanks to the work of governments and advocates: wind turbines should not be installed...
near nesting grounds for endangered bird populations or in the common routes of bats; small-hydro projects can affect aquatic ecosystems if not carefully installed; and appropriate disposal and recycling strategies for RETs are needed at the end life, particularly for technologies such as batteries and photovoltaics. Biomass sustainability is also an important consideration given the potential impacts of biomass cultivation and energy conversion on land and water use, food prices, biodiversity, and air emissions (Singer, 2011; Vis et al., 2010).

- There are also clear and well-documented environmental advantages for RETs: RETs are more suitable than diesel for sensitive ecosystems because they not only produce less pollution, but also because they reduce the risk of oil spills. The risks of oil spills are magnified in remote areas not only because of the fragility of their ecosystems, but because of the complicated logistics involved with clean up in isolated areas. RETs are also low- or no-carbon technologies. Remote areas are among the most vulnerable to the threats of climate change. The use of RETs in remote areas provides them an opportunity to demonstrate leadership in low-carbon technologies and integration. Such leadership is important not only for community resilience, but also to building worldwide expertise in high-penetration renewable energy systems.

3.1.9 TECHNICAL CONSIDERATIONS

3.1.9.1 ENERGY SCENARIOS

Many current future energy scenarios are not relevant to remote areas. Remote areas by definition will not be connected to international “super grids” nor will they have access to the centralized natural gas infrastructure that would make natural gas transitions feasible.

The most practical and cost-effective energy future in most remote areas is a renewable energy future. Remote areas will be unable to use natural gas as a “bridge” and will therefore need to contemplate moving in the near-term towards high penetrations of renewable energy in order to transition away from diesel. This section reviews the key concepts related to high penetrations of renewable energy in remote areas, with a focus on the electricity, transportation, and heating/cooling sectors. Several recent studies focus on global scenarios for high renewable energy penetrations (e.g. up to 100%) (Droege, 2009; Jacobson and Delucchi, 2009; Singer, 2011; Teske et al., 2010). This section focuses on the unique concerns of remote communities, but uses these studies as reference points.

3.1.9.2 ELECTRICITY

The challenge of achieving high penetration levels of renewable electricity is more complex than doing the same for renewable heating or transportation because electricity is more difficult to store and because supply and demand must always be in balance in order to ensure system reliability. This section explores some of the technical issues related to grid integration.

Integrating renewable electricity into remote electricity grids requires a more granular understanding of local conditions than may be necessary in non-remote areas. The major technical differences between remote and non-remote areas are the comparatively small grid size, the shape of the electricity load

The island of Kauai in Hawaii discourages wind turbines to protect their native bird populations.
(e.g. peaks due to daily and seasonal variability), and the characteristics of existing electricity infrastructure (for example, remote areas utilize diesel for electricity generation, whereas non-remote areas generally do not). When contemplating a transition to high penetrations of renewable electricity in remote communities, the key technical questions that need to be answered include:

- What are the community’s energy needs? Can they be reduced or addressed more efficiently?
- What is the available infrastructure? How will these RETs integrate with the existing energy supply infrastructure?
- What indigenous energy resources are available (wind, sun, biomass, geothermal, hydro)?
- How can these energy resources be integrated in a way that balances local considerations and supplies residents with reliable electricity?
- What penetration level is the most cost effective and makes sense for each of these resources and how can these resources be best used?

By answering these questions through research and planning, remote areas can position themselves to implement new policy strategies. This section explores each of these questions in greater detail.

ENERGY NEEDS AND ENERGY EFFICIENCY IN REMOTE AREAS

As with heating and transportation, the first consideration in any energy system is to ensure that energy demand is limited to the fullest extent possible. Similar to non-remote areas, electricity demand management strategies in remote areas include energy efficiency, demand management, and behaviour change strategies that support energy conservation. A key difference between non-remote and remote areas is that the value of managing energy use is greater due to higher cost of generation and therefore the range of cost-effective measures is greater (MAFA and Northern Economics, 2004). The other considerations related to energy efficiency in remote areas include:

- Remote areas may not have ready access to the most efficient technologies and appliances through their established supply channels.
- Water and wastewater infrastructure can also be highly energy intensive and costlier than in non-remote areas (e.g. in Northern Canada water treatment and hauling makes water 125 times more expensive than in average urban regions (Waller et al., 2003). In warm areas with limited water availability, desalination facilities can represent a proportion of total electricity demand. Factors such as these make freshwater conservation systems such as low-flow fixtures or rain catchment systems significant contributors to energy efficiency.
- Housing may be less efficient in remote areas. For example, in Scotland 13% of remote households were classified as having a good energy efficiency rating compared to 31% in accessible rural areas and 55% in the rest of Scotland (The Scottish Government, 2010a).
- Remote areas may also not have as much access to information on best practices and effective behaviours for energy consumption. Similarly, remote areas may lack strong price signals to conserve energy if energy prices are heavily subsidized.
DEMAND CHARACTERIZATION
Properly characterized demand can more fully leverage the cost-saving benefits of RETs. Energy systems are sized to meet specific load levels, and should be optimized to provide power at expected levels. There are a number of common load variation scenarios in remote areas that should be considered when integrating RETs in a remote area:

- **Changing seasonal demand:** Both renewable and diesel generation may need to be kept in reserve for fluctuating seasonal demand related to primary economic activities, such as fishing or tourism.

- **Periods of small demand relative to average demand (in particularly fluctuating daily demand profiles):** It can be technically difficult for large capacity energy grids to efficiently serve load if demand decreases substantially. This is particularly a challenge for large diesel generators that are unable to turn-down to a sufficient level. A properly designed integrated hybrid system that includes generators of different sizes should be able to meet load at all times for the year.

- **Periods of high demand relative to average demand:** The requirement to assure supply at peak times is expensive in both remote and non-remote areas. Energy supply delivery systems must be sized to the maximum peak load, even if it only occurs occasionally. A system that is sized for a peak that rarely occurs is said to have low asset utilization. Low asset utilization can be particularly acute in remote areas where there is low load diversity and where therefore individual loads can drive system peaks (Lovins et al., 2002). System operators often address low asset utilization by providing price signals, such as time-of-use energy rates, to consumers\(^9\). In addition to pricing strategies, energy planners can attempt to address peaks by fuel switching to renewable technologies (e.g. solar thermal) or using renewable energy for peak shaving (e.g. PV or biomass) (Byrne et al., 1996).

- **Demand growth:** Rapid demand growth can require additions in both generating capacity and the systems that manage it. Renewable energy installations can also trigger disproportionate or unexpected demand growth when they increase energy availability. In the Maldives, for example, recent installations of solar and battery hybrid systems were reconfigured to be grid connected when there was a 50% increase in energy demand in the service areas (Nashid, 2011). In Floreana, Galapagos (see Case Study) the improved electrical availability encouraged residents to invest in refrigerators and other new appliances, which led to 54% demand growth over 4 years (~11% annually). Increased demand from increased availability can have substantial implication for grid integration and should be an important part of early system planning to maximize benefits.

UPGRADING EXISTING INFRASTRUCTURE
The existing electricity generating equipment in remote areas, including generators, control equipment, facilities, transmission and distribution equipment, sensors, and other electrical equipment, may require modifications in order to integrate with renewable technologies. Diesel gensets, for example, need to be assessed to determine their ability to complement intermittent renewables. Modern diesel generators are designed to change speeds to accommodate shifts in the loads they serve. At low penetrations of renewables, diesel generators can ramp down to accommodate renewable generation when the sun

\(^9\) e.g. use of electricity dispensers to manage energy daily allowance and maximum current overload
shines or the wind blows just as they would ramp down if loads they serve are shut off. Some remote areas have older, low-speed diesel engines, however, that cannot as easily adjust to even comparatively low penetrations of renewable generation or that need to manually adjusted (Baring-Gould and Corbus, 2007; Drouilhet, 2001). Such systems either need to be retrofitted, augmented with newer gensets or replaced.

A properly designed and well-maintained electrical distribution grid is also a critical asset for integrating renewable electricity. Grids in remote areas, for example, can experience electrical losses of 20% or higher and may need to be strengthened and repaired. Addressing line losses in the grid is often a necessary first step in order to avoid the need for oversized generation.

It is also important to realize that the existing electricity infrastructure often represents a sunk cost. In many cases, utilities or individuals may not yet have recovered earlier investments in existing infrastructure (e.g. diesel generation). This makes it challenging to displace or dislodge existing generation without compensating system owners for prior investments. However, diesel gensets as well as some renewable energy technologies are inherently “modular”, i.e. they can be moved from one area to another. In many cases, a secondary market for gensets, solar panels, or wind turbines exists, reducing the risks of stranded costs. Grid-related assets can also be displaced, though somewhat less easily.

**ASSESSING AVAILABLE RENEWABLE ENERGY RESOURCES**

There is a broad range of available renewable electricity resources, including wind, solar, biomass, geothermal, hydropower, and ocean energy. Non-remote areas can readily combine networks of different resources by building transmission infrastructure that can transmit renewable electricity over long distances. This enables non-remote areas to assemble portfolios of renewable generation with complementary characteristics. Non-remote areas can also count on the geographic dispersal of renewable generation to help balance the system. Remote areas must instead rely primarily on whatever renewable energy sources are available to them and must evaluate renewables not only for their availability but for their electricity generation characteristics. The three types of electricity generators are listed below, with the corresponding renewable resources listed in parentheses.

---

10 In addition to these resources, there are other abundant resources that are beginning to be tapped, but which are still at an early stage and that in order to be tapped require further technological and market development before they can be implemented at scale. It is still worthwhile for remote areas to keep such resources in mind as pilot project sites or for their potential use in the mid or long-term future. Ocean, tidal, hydro-kinetic, and third-generation biofuels (algae and cellulosic ethanol) are among these emerging resources that are beginning to be tapped by a new generation of technologies. Hydro-kinetic turbines are an integrated turbine generator to produce electricity in a free flow environment. It does not require a dam or diversion and can be placed in rivers, canals, tidal waters, or ocean currents. A hydro-kinetic turbine was recently installed on a pilot basis in Fort Simpson in Canada (Thompson, 2010).

11 Although wind may not be blowing in one part of the service territory, for example, it might be blowing in another. This geographic diversity allows for an overall smoothing of intermittent generation in the supply mix instead of all the wind being either “on” or “off” at once (Lovins et al., 2002).
• Base load (hydro, geothermal): Base load generators produce electricity most efficiently at a single output level and do not respond well to changes in demand. Geothermal and some hydroelectric plants are often designed for base load operation. Base load plants cannot be actively used to support the integration of other types of generators because they cannot be easily turned “on” or “off” in response to the climactic conditions which may affect other renewables.

• Dispatchable (e.g. dispatchable hydro, biodiesel, geothermal, ocean energy): Dispatchable generators are designed to vary their power output and can be readily turned off and on. Diesel generators, for example, are dispatchable. Dispatchable generators are integral to the integration of intermittent renewable generation since they can quickly adjust their output to compensate for changes wind and solar output. Remote communities that are seeking low- or medium-levels of renewable penetrations will likely rely on dispatchable diesel and in some cases propane power. Communities that are seeking high levels of renewable penetration will either need to have available hydropower sources that can be configured to be dispatchable or must utilize biodiesel. Hydropower requires a reservoir for dispatchability and remote communities will require the land area to build one. Moreover, hydropower is vulnerable to droughts, which are likely to increase in certain areas as the climate changes.

• Intermittent (wind, solar): Intermittent generators provide energy, but do not reliably generate power at all times. Intermittent technologies include wind turbines and photovoltaics panels. Most areas will have either a strong wind or solar resource. Wind and solar power can typically be integrated into remote community grids at low levels without the need for new equipment or control strategies. Existing diesel generators should be able to automatically adjust to accommodate renewable generation. Higher penetrations of wind and solar, however, will require more sophisticated control technologies and storage (Baring-Gould and Corbus, 2007).

INTEGRATION AND RELIABILITY

There are two critical considerations for ensuring a well functioning electrical grid. The first is to ensure energy availability, meaning that the grid and power system should designed to be available at all times (i.e. 24-hour power). The second is reliability, which refers to the ability to supply electricity continuously without interruptions. Renewable energy generation can expand the availability of electricity from part-time power to 24-hour power (e.g. as has been the case in the Isle of Eigg, Scotland and Floreana, Galapagos case studies).

Renewable electricity can have different impacts on electricity reliability, depending on the type of generator and the total amount of electricity on the grid. Increases in the amount of baseload or dispatchable renewable electricity connected the grid can have a positive impact on grid reliability. Increasing the amount of intermittent renewable electricity, however, can negatively impact power reliability if it is not appropriately planned for and managed.

The penetration level of intermittent renewable electricity can be split into 3 categories: low (typically <20% average energy) medium(typically between 20-50% average energy), and high (typically >50%

12 Biodiesel plants can also be configured to supply baseload generation.
average energy). The actual division between penetration levels will vary between systems and will depend on the ability of the dispatchable generators to manage the variable production from renewables. Low penetration systems are simpler to design and operate, and in many cases very little additional equipment is necessary to have a reliable system. As the penetration level increases, the necessary equipment and design challenges increase (Lilienthal, 2007).

- At low penetration levels, modern diesel generators should be able to automatically adjust to account for variable output of renewable electricity generation without the need for additional equipment.

- At medium penetration levels, renewable electricity may be sufficient to require some of the diesel generation to be shut down and/or to switch to a smaller diesel generator. Under these circumstances, the remaining diesel generation may not be sufficient to automatically compensate for variations in renewable energy output. In order to maintain reliability, additional control and stability systems need to be introduced. These can include introducing storage, new loads which can absorb excess electricity, and/or enabling renewable electricity generation to reduce power output as necessary. On Reunion Island, for example, renewables are curtailed when their peak instantaneous energy exceeds 30% (see Reunion case study). The power system also requires systems and strategies to compensate for sudden decreases in renewable electricity output. These can include the use of controllable loads that can be “shed” or turned off as output decreases or diesel engines with fast-start capabilities.

- At high penetration levels, it is possible that electricity from intermittent renewable energy sources could be sufficient to require that the entire diesel generating fleet be shut off. Under these cases, a significant amount of short-term storage may be required to ensure power reliability. As intermittent renewable electricity declines, the storage systems dispatch power as a “bridge” until the renewable generator’s output increases again. If the generation does not start again, then the system falls back on the idled diesel generators sets. High penetration systems require a much higher level of system integration, including more sophisticated system controls and additional equipment.

This description assumes that diesel will play the role of the dispatchable power supply. In a 100% renewable electricity scenario, renewable generation such as hydropower or biodiesel would play the role of the dispatchable resource.

INFRASTRUCTURE FOR INTEGRATING RENEWABLES

There is a range of specialized equipment that needs to be considered when contemplating high penetration scenarios for renewable electricity:

---

13 Renewable resource penetration can be described using several metrics, including peak instantaneous penetration, penetration based on peak load, penetration based on system capacity or penetration based on energy. All of these considerations are important when completing a detailed system design. This report only uses average energy to simplify the discussion.
• Storage. There are several different roles that storage can play. These include providing the “spinning reserve” capability to bridge lulls in renewable energy output, ensuring power quality by smoothing out the ramping up and ramping down of renewable generation, and playing an arbitrage function in which renewable electricity stored during periods of time when energy has low value and then dispatched when energy has a higher value (Lilienthal, 2011). Different storage technologies are able to play different roles. Flywheels, such as those deployed in Coral Bay, for example, can provide short-term storage on the order of seconds or minutes to meet spinning reserve needs. Batteries can provide storage for hours or days’ worth of energy, whereas pumped hydro systems store enough energy to meet demand for several days. There is also a great deal of interest in hydrogen as a storage medium, which is discussed in greater detail in Text Box 3. A comparison of different storage technologies in different remote areas is recommended as a topic for further research.

• Secondary loads. Also known as “dump loads”, secondary loads are set up to absorb excess electricity that cannot be used elsewhere on the grid when renewable generation achieves its maximum output. Wind turbines in cold remote areas, for example, can be configured to supply electric heat to thermal loads.

• Low-load diesels. Diesel generators typically have a threshold below which they can no longer reduce their output and need to be turned off. Specially designed low load diesels are able to reduce their output below that of conventional models but still remain “on” and ready to ramp back up if renewable energy output subsides. This can help ensure reliability in higher renewable energy penetration scenarios.

• Remote monitoring. Monitoring equipment can be installed to enable grid operators to actively track the health of the power system and intervene to make adjustments under special circumstances.

Although the commercial deployment of high penetration renewable electricity systems in remote areas is a recent development, the industry has advanced significantly. Existing high penetration systems have demonstrated that state-of-the-art integration and control strategies can provide stable AC electricity without issues such as voltage sags, overvoltage, etc. A monitored PV/diesel micro-grid with very high PV
penetration in Ecuador, for example, had a downtime in 2011 of only 51 minutes over the course of the year\textsuperscript{14}.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6.png}
\caption{Example of a solar hybrid micro grid (Source: TTA)}
\end{figure}

**OPTIMIZING HYBRID SYSTEMS**

A properly designed remote power system with RETs can produce reliable electricity 24-hour-a-day 7 days a week. Multi-source power systems leverage the benefits of each technology to provide reliable power. For example, a renewable resource such as wind or PV can be used to provide the bulk of the community’s energy needs, while storage is used to shift surplus renewable energy from periods of low demand to periods of high demand. A liquid fuel generator (or hydro, if available) can be turned on when the other sources are unavailable, which ensures availability at all times.

Hybrid power systems can also leverage the strengths of different technologies to provide lowest cost power generation. Figure 7 below shows the results from an optimal economic analysis using the HOMER software to estimate the lowest net present cost electricity system for a remote town with 150 residents (70 kW average demand) near the Arctic Circle\textsuperscript{15}. The solution with the lowest levelised cost of energy (LCOE) is determined primarily by the strength of the wind resource and the cost of diesel. The only two potentially cost effective alternatives are a scenario with only diesel gensets (shown in blue) and a multi-source hybrid wind/diesel/battery system (represented by the hashed yellow region). As can be seen in the figure, if the average wind speed in the site exceeds 5.5 m/s, a hybrid wind/diesel/battery system will provide the lowest cost energy. However, as the price of diesel increases, the resource

\begin{itemize}
\item \textsuperscript{14}Project developed by TTA, monitored data
\item \textsuperscript{15}Analysis is based on load data from the “Wind-Diesel system” sample file available from www.homerenergy.com. Economic and performance data was updated to be representative of current market conditions.
\end{itemize}
needed to make wind cost-effective decreases – if diesel fuel costs $1.40/L (€1.07/L), the average annual wind speed needed to make wind cost effective is only 4.5 m/s.

![Optimal System Type Graph](Image)

**Figure 7:** Optimal system type graph for providing electricity to a 150 person town near the Arctic Circle. Source: HOMER

The potential to economically optimize renewable electricity in remote areas further reinforces both the opportunity and the necessity of careful and integrated approaches to system planning. It should be noted, however, that systems can be iteratively expanded over time. On King Island in Tasmania, Australia, for example, the amount of renewable penetration has been slowly increased over time and its success is being cited as an affordable pilot for technologies that can be later deployed into larger grids (Hydro Tasmania, 2010).

High penetrations of renewable electricity are possible in remote areas. It is also possible to achieve 100% renewable electricity penetration, but this is most readily achieved in when intermittent generators are combined with renewable base load and dispatchable generation such as hydro and biodiesel. It is possible to also have systems that combine only intermittent renewable energy systems and storage (i.e. without baseload or dispatchable power), but there are currently technical hurdles to accomplishing this for systems larger than 200kW. There are ongoing attempts to accomplish wind/PV/storage hybrids (e.g. El Hierro Island and Bonaire) and this may increasingly become an option as control strategies grow more sophisticated.

If 100% penetration scenarios are not technically or economically feasible, it is reasonable to use hybrid systems to achieve a renewable energy penetration level that balances:

- the locally available resources,
- technical limitations (in particular those related to system size),
- environmental concerns, and
- the provision of reliable, available energy for local residents.
Each remote area will have a different appropriate amount of renewables based on how these considerations are balanced.

**Text Box 3: Hydrogen as an energy storage medium**

*Prepared by Dr. Federico Villatico, IEA HIA Operating Agent for Task 29, Distributed and Community Hydrogen (DISCO H2)*

Hydrogen is a versatile energy vector that can complement other technologies (like electricity and bio-fuels) to enhance the capability of the whole energy system to cover energy demand in the short to medium-long term.

Global energy policies are targeting a progressive de-carbonisation. While there might be some differences in the selected implementation processes by macro areas (EU 20/20/20 policy, America, Asia), the main common approach is to increase energy efficiency and the penetration of renewables in the energy mix as much as possible.

Within this context, hydrogen is capable of playing an important role as a medium to store the intermittent energy coming from renewables, thereby helping to match the supply of unpredictable renewable energy production with planned energy demand. The Figure below depicts how hydrogen may cover a wide spectrum of power applications ranging from a few kilowatts up to a few megawatts, overlapping especially with battery-based solutions.

Modern energy grids need an accurate design if instability issues are to be prevented as the renewable energy fraction increases. In smart grids, excess energy from RE can be stored in the form of hydrogen and re-used during periods when renewables are not producing, and/or for stabilising the grid operation (peak shaving).

In terms of final energy uses, hydrogen enables renewable energy technologies to access the transportation sector for both electric (with fuel cell) and mechanical (with internal combustion engine [ICE]) traction vehicle types, whether as pure hydrogen or a mixture with natural gas (in quantity usually up to 30% by volume). Hydrogen can be combusted without major modifications in current ICES with advantages in terms of fuel consumption and reduction of pollutant emissions.

Several projects worldwide are presently working on the integration of hydrogen as a medium for storing renewable energy. Various past and present Tasks of the International Energy Agency Hydrogen Implementing Agreement (IEA HIA) -- Tasks 18, 24, 29 among others -- have analysed and monitored such projects. Remote communities (e.g. rural, islands) often offer interesting off-grid applications for electricity, heat and hydrogen, which that may be used as case studies for the development and testing of economically viable solutions that can be replicated in similar locations around the globe.
TRANSPORTATION

Transportation also accounts for a significant percentage of energy usage for remote communities. Road travel is reduced compared to non-remote areas because of remote areas’ geographic isolation and/or lack of road networks. Sea and air transportation for the purposes of commerce and travel, however, can be significantly higher on a per capita basis than in non-remote areas. The primary renewable resources for transportation are biofuels such as biodiesel and ethanol.

The issues related to biofuels for transportation in remote areas are similar to the considerations for biofuels and biomass for renewable thermal (Section 3.1.9.2). These include the fact that biofuels in quantities sufficient to meaningfully impact the transportation sector are not likely to be locally available in most remote areas. In the near term, remote areas will have to weigh the pros and cons of trading imported biofuels for imported diesel. The same is true in most cases for the use of biomass sources for electricity generation, heating, or both.

Note: NAS = Sodium Sulfur; Li-ion = Lithium ion; Ni-Cd = Nickel Cadmium; PQ = Power Quality; UPS = Uninterruptible Power Supply; SMES = Superconducting magnetic energy storage.

3.1.9.3 TRANSPORTATION

Transportation also accounts for a significant percentage of energy usage for remote communities. Road travel is reduced compared to non-remote areas because of remote areas’ geographic isolation and/or lack of road networks. Sea and air transportation for the purposes of commerce and travel, however, can be significantly higher on a per capita basis than in non-remote areas. The primary renewable resources for transportation are biofuels such as biodiesel and ethanol.

The issues related to biofuels for transportation in remote areas are similar to the considerations for biofuels and biomass for renewable thermal (Section 3.1.9.2). These include the fact that biofuels in quantities sufficient to meaningfully impact the transportation sector are not likely to be locally available in most remote areas. In the near term, remote areas will have to weigh the pros and cons of trading imported biofuels for imported diesel. The same is true in most cases for the use of biomass sources for electricity generation, heating, or both.

Note: NAS = Sodium Sulfur; Li-ion = Lithium ion; Ni-Cd = Nickel Cadmium; PQ = Power Quality; UPS = Uninterruptible Power Supply; SMES = Superconducting magnetic energy storage.

3.1.9.3 TRANSPORTATION

Transportation also accounts for a significant percentage of energy usage for remote communities. Road travel is reduced compared to non-remote areas because of remote areas’ geographic isolation and/or lack of road networks. Sea and air transportation for the purposes of commerce and travel, however, can be significantly higher on a per capita basis than in non-remote areas. The primary renewable resources for transportation are biofuels such as biodiesel and ethanol.

The issues related to biofuels for transportation in remote areas are similar to the considerations for biofuels and biomass for renewable thermal (Section 3.1.9.2). These include the fact that biofuels in quantities sufficient to meaningfully impact the transportation sector are not likely to be locally available in most remote areas. In the near term, remote areas will have to weigh the pros and cons of trading imported biofuels for imported diesel. The same is true in most cases for the use of biomass sources for electricity generation, heating, or both.

In the Faroe Islands, 12% of oil derivatives is for road and air transport, 12% is used for transport vessels, while almost 30% is used for fishing vessels (Hagstova Forøya, 2011).
In the longer-term, the competing demands on biomass for energy across different sectors may limit its broad availability in the transportation sector. This concern has been reflected in the European Commission’s increased flexibility on the share of the 20/20/20 targets that must be represented by biofuels. The *Energy Report*, for example, assumes that biomass is utilized only as a last resort to supply energy to applications that cannot be met by other means. In the WWF scenario, biomass supplies 13% of heat in buildings and 13% of electricity for the purposes of balancing intermittent power. Biomass also supplies 60% of industrial and transportation fuels. Even with these restrictions, the report estimates that biomass would require the use of 1/6 of all arable land (Singer, 2011), which may be challenging given future projections of food demand (see, e.g. DBCCA, 2009a). The Energy [R]evolution report, meanwhile, assumes that biomass in a high penetration renewable energy scenario is primarily committed to stationary applications and that biofuels for transportation are limited by the sustainability of raw materials (Teske, 2010).

Taking the potential limitations of biomass into account, there are several considerations for remote communities attempting to achieve high penetrations of renewable energy in the transportation sector. First, there are some energy efficiency and conservation opportunities available to remote communities in the transportation sector, such as the adoption of highly efficient vehicles, maintenance and behavioral practices related to automobiles (e.g. keeping tires inflated and driving at optimally efficient speeds) and retrofit technologies for ships such as contra-rotating propellers or kites and sails for cargo vessels (Corbett and Fischbeck, 2002; DNV, 2010). Other conventional strategies may be less applicable, however. Remote communities do not typically have the ability to transition to rail transport, for example. Ride sharing programs for automobiles, although beneficial, may not have a significant impact in remote communities with small amounts of road travel. The largest efficiency gains for vehicles are likely to come from more efficient vehicles being developed and supplied by the manufacturers. A key concern, however, is how quickly remote areas will gain access to new models given their relatively small market sizes and comparative isolation. Also, the trend to lighter and smaller vehicles may not be appropriate for the demands of some more rugged remote areas.

A second consideration is the availability of fuel alternative beyond biofuels. There is general consensus among recent global high-penetration renewable energy scenarios that a significant proportion of light road vehicles will need to be fueled by electricity from renewable sources (Jacobson and Delucchi, 2009; Singer, 2011; Teske et al., 2010). For remote communities, a switch to electric vehicles could also support grid integration: electric vehicles can absorb excess renewable generation and can also potentially be configured to supply power back to the grid when necessary (Letendre et al., 2006; H. Lund and Kempton, 2008). Electrification of road vehicles would also work well for remote areas given the short distances that need to be traveled. Electrification is not a practical strategy for travel involving longer distances, including maritime transportation (e.g. shipping and fishing) at this stage.

In evaluating sustainable transportation options for remote areas such as Greenland and the Faroe Islands, the Nordic Working Group on Renewable Energy (NWGRE) concludes that ships will likely need

---

17 This report does not take into account potentially limiting factors such as the availability of materials to manufacture alternative fuel vehicles. Lithium ion batteries, for example, are currently the leading battery technology for electric vehicles. There may not be enough lithium, however, to sustain the electric vehicle fleet of the future (Tahil, 2007).
to continue to utilize biofuels or be powered by hydrogen (COWI A/S, 2009). Although some analyses argue that the world economy should be based on hydrogen (Rifkin, 2003), hydrogen remains a controversial energy carrier for transportation because of the amount of energy required to produce it and because of the challenges inherent in establishing new distribution architecture (Bossel, 2006; Romm, 2004), among other factors. The centralized nature of maritime refueling infrastructure (i.e. in ports), however, alleviates the concern of building an extensive hydrogen distribution network (Singer, 2011). To date, there have been some demonstration projects of wind/hydrogen hybrid systems to supply electricity in remote communities (e.g. Ramea in Canada, Unst in Scotland, and Utsira in Norway) but there has only been limited use of hydrogen in maritime applications.

### 3.1.9.4 HEATING

Thermal energy demand accounts for 40-50% of global final energy consumption and includes space and water heating for buildings as well as the heat required for industrial and manufacturing processes. The IEA estimates that space heating and domestic water heating account for 75% of the energy used in buildings (Langniss et al., 2007). Thermal energy demand can be a significant share of demand in remote communities, particularly in northern communities with long winters and cold/temperate remote areas (e.g. in Nólsoy community in the Faroe Islands, almost 80% of household energy demand is heating). The primary renewable sources of thermal energy include biomass thermal, solar thermal, and geothermal heat.

#### BIOMASS THERMAL

Biomass thermal can include a broad range of different fuel types, ranging from waste streams such as the black liquor produced during paper manufacturing to sustainably harvested willow trees. Biomass currently provides the vast majority of renewable thermal energy globally. The feasibility of biomass for thermal energy in certain remote communities is limited, however, because many do not have a naturally available source of biomass or have depleted existing biomass through unsustainable harvesting (i.e. deforestation).

One option would be for remote communities to cultivate biomass energy crops. Remote communities, however, tend to rely heavily on food imports and utilize available arable land for cash crops. Energy crops would likely compete with and displace other land uses and thereby negatively impact the balance of trade (e.g. decrease cash crop exports and/or increase food imports). A second option is to import biomass. Biodiesel, for example, can be imported through the same distribution channels that are currently used for diesel and could also be combusted utilizing much of the existing thermal energy infrastructure (e.g. as is being pursued in Bonaire and Floreana - see Appendix A). Another alternative is wood pellets, which are a readily transportable and distributable...
form of biomass. The international wood pellet market has expanded dramatically during the past several years with significant amounts of new capacity coming online (Peska-Blanchard et al., 2007). Wood pellets could also be distributed through the same channels that currently distribute diesel fuel, but would require specialized equipment such as wood pellet delivery systems (e.g. trucks), bulk and onsite wood pellet storage facilities, and the installation of wood pellet stoves and boilers (Egger et al., 2010). While importing biomass could create opportunities to displace diesel, it would also negatively affect the balance of trade and remote communities would still face the risk of supply disruptions. In the long-run, high penetrations of biomass in remote communities may also be constrained by international trends. There are limits on the supply of biomass – both in terms of sustainability and of available land – that will become increasingly apparent as the world strives to increase the share renewable energy.

A few options for supporting biomass thermal against this backdrop include increasing the efficiency of existing biomass utilization, as has been done on Samsø in Denmark, where district heating systems are used to heat local homes and businesses. Other options include increasing the use of non-biomass renewable electricity for heating and cooking to decrease biomass demand, and the expanded use of heat pump technologies.

**SOLAR THERMAL**

Solar thermal can be used in a wide range of applications including space heating, industrial process heating, and to drive absorption cooling, but the majority of solar thermal capacity installed to date has been used to heat domestic hot water. There are some notable exceptions to this, however. According to the IEA, the majority of new capacity installed in Germany and Austria in 2009 was in systems that provide both space heat and water heat ("combi-systems") (Weiss and Mauthner, 2011). Solar thermal systems have been successfully demonstrated throughout the world and in remote communities. Barbados, for example, has the third highest solar thermal capacity per capita in the world behind Cyprus and Israel. Another island with a high penetration of solar hot water systems is Reunion Island, in the south Indian Ocean (see Appendix A, Case Study 4D).

**GEOTHERMAL ENERGY**

Geothermal heat includes the direct use of heat from the Earth, perhaps best exemplified by geothermal baths and swimming facilities. By 2010, there were 15 GW of installed direct use systems globally. Direct use of geothermal heating is site specific and may not be an option for many remote communities. There were also 35 GW of geothermal heat pumps installed by the end of 2010, up from 15 GW installed in 2005. (J. W. Lund et al., 2010). Geothermal heat pumps can be installed almost universally and can provide up to 100% of heating demand by harnessing the relatively constant temperature of the Earth.21

The ability of remote communities to achieve 100% of their thermal energy from renewable sources will depend to a large extent on their locally available resources and their thermal demand. Specific considerations for different types of remote areas to achieve high heat penetrations are discussed in Section 3.2. There are several general considerations for policymakers seeking to support high penetrations of renewable heat in remote communities. The first is that there are likely significant

---

21 Some analyses classify geothermal heat pumps as a source of renewable thermal energy (EREC, 2007), whereas others classify geothermal as a demand-side energy efficiency resource (Singer, 2011).
opportunities for improving thermal efficiency (e.g. insulation, efficient windows, air sealing, etc.), although this varies by location. A recent study estimates that potential improvements to heating efficiencies can range from 5% in OECD Pacific countries to 40% in Europe. Overall, it is estimated that improved heating efficiency can reduce demand by 24% globally despite improved standards of living (Teske et al., 2010).

A second consideration is that thermal energy is often closely associated with the load it serves, unlike electricity. Most renewable heating systems are onsite, instead of being connected to a central “grid” for renewable thermal energy. There are exceptions to this in some countries. For example, there are currently 115 large-scale solar thermal systems that are hooked in to district energy systems internationally (Weiss and Mauthner, 2011). IEA-RETD countries vary in their usage of district heating in remote areas. Japan, for example, had 148 district heating districts in 2007, but none of these served remote areas (Koshiba, 2009). In Canada, by contrast, there are 17 district energy systems serving remote communities in Nunavut, the Yukon, and Northwest Territories. Different renewable heating technologies also serve different end uses and are not necessarily interchangeable like electricity generators (e.g. geothermal heat pumps for space heating, solar air heaters for air heating, solar water heaters for water heating). Finally, the performance of the renewable heating system can be directly linked to the design of the building it serves and therefore an integrated approach to designing both the system and the load may be required (e.g. especially for heat pumps).

A third consideration is the interplay between thermal energy and electricity. Electricity can be used to provide heat. Given the long-term sustainability concerns related to biomass, several recently published global renewable energy scenarios envision that renewable electricity will be utilized to increasingly supply demand for heat in order to free up sustainable biomass for other uses (Singer, 2011; Teske et al., 2010). Similar considerations may also drive the utilization of electricity for heat in remote areas. As discussed, the use of electrical heat loads to absorb excess renewable electricity generation can support the integration of intermittent resources.

### 3.2 SPECIFIC CONSIDERATIONS BY CATEGORY

This section builds on the discussion of general considerations by identifying representative categories of remote areas. For each category, renewable energy development considerations that are of particular or unique relevance are identified with a primary focus on environmental conditions, energy demand and infrastructure considerations, the primary renewable resources available, and specific considerations related to high penetration scenarios.

The six categories are

1. Remote areas with long winters
2. Remote areas with temperate climates
3. Small remote areas with warm climates

---

---

22 See Canadian District Energy Association: https://www.cdea.ca/projects/map
4. Large remote areas with warm climates
5. Research stations and National Parks
6. Remote areas in developing countries

The categories were developed following an in-depth assessment of different factors that influence energy usage in remote areas, including technical, socio-economic, institutional, financial, and environmental considerations. The categories were developed in order to a practical and simple starting point for remote area energy analysis. The first four remote area categories are organized primarily according to size and to climate since these are main determinants of both demand and available renewable energy supply. The final two categories reflect circumstances that may require specific technological or policy approaches. This section focuses primarily on the technical considerations relevant to specific categories. Other general considerations (e.g. socio-economic and environmental) vary widely from area to area and are difficult to meaningfully assign to specific categories.

Table 1 below summarizes each of the categories of remote areas and lists examples from around the world. Examples for which case studies have been conducted are in bold.
Table 1: Remote Area Categories

<table>
<thead>
<tr>
<th>Main Characteristics</th>
<th>Example remote areas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category 1: Remote areas with long winters</strong></td>
<td>Small communities throughout rural Canada (CAN), small Greenland communities (DK), Iqaluit, Nunavut (CAN), <strong>Ramea Island (CAN)</strong>, Old Crow, Yukon (CAN), Small communities in Norway’s north mainland (NOR), Norwegian islands (NOR), Remote Alaskan communities (US), Baker Lake, Nunavut (CAN), <strong>Kodiak Island, Alaska (US)</strong>,</td>
</tr>
<tr>
<td>Communities may have a seasonally limited access to fuels due to icy conditions that make them inaccessible during winter periods – therefore reliable storage of fuels is a priority. Heating is the main driver of energy demand, which leads to increased energy needs in winter months. Most local transportation needs are for short local trips, although fishing is a common economic activity. Public transport options are often limited. The main renewable resource is wind although solar may provide useful energy during summer months. Hydro and geothermal may be available at specific sites.</td>
<td></td>
</tr>
<tr>
<td><strong>Category 2: Remote areas with temperate climates</strong></td>
<td><strong>Isle of Eigg (SCO)</strong>, Japanese outer islands (JAP), AcENSION Island (UK), King Island, Tasmania (AUS), Graciosa Island (PT), Stuart Island (CAN), <strong>Faroe Islands (DK)</strong>, Utsira Island (NOR), Shetland Islands (UK), Falkland Islands (UK), Fair Isle (UK), Isle of Wright (UK), Chiloe Archipelago (CHILE)</td>
</tr>
<tr>
<td>Temperate remote areas will have less harsh winter conditions than areas with long winters. Most mainland temperate areas that would have been considered remote have been already electrified (except for isolated mountain areas like the Pyrenees), so most temperate remote areas are islands. Heating is a main requirement during winter months, although electricity needs may still be higher in summer months, in particular places with a large tourism industry. The main resources available are wind and solar, although hydro and geothermal may be available in some locations.</td>
<td></td>
</tr>
<tr>
<td><strong>Category 3: Small remote areas with warm climates</strong></td>
<td>Sint Eustatius (NL), Saba (NL), Sint Maarten (NL), Saint Martin (FRA), Niue (NZ), Tokelau (NZ), Pitcairn Island (UK), Peter Island (BVI), <strong>Florene, Galápagos (EC)</strong>, Gomera, Canary Islands (SP), <strong>Coral Bay, WA (AUS)</strong>, Iriomote Island (JP), Aogashima Island (JP)</td>
</tr>
<tr>
<td>Most of these areas are represented areas highly vulnerable to floods, hurricanes, and other climate related disasters. Energy needs are mainly for end-use electricity, with limited demands for cooling. Heating needs are primarily for household water heating. Local energy needs differ significantly from tourists’ demands, who will demand significantly more energy per capita. Transport needs are small locally, but there are considerable sea and air transportation needs for tourists. The main resource available is solar, while wind, biomass, and hydro availability is more site specific.</td>
<td></td>
</tr>
<tr>
<td>Main Characteristics</td>
<td>Example remote areas</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Category 4: Large remote areas with warm climates</strong></td>
<td>Bonaire (NL), Anguilla (UK), American Samoa (US),</td>
</tr>
<tr>
<td>Similar to small remote areas with warm climates, these large remote areas are</td>
<td>San Andres (COL), Saint Barthelemy (FR), Wallis and</td>
</tr>
<tr>
<td>vulnerable to extreme weather conditions. Energy needs are also driven by tourism,</td>
<td>Futuna (FRA), Cook Islands (NZ), Montserrat (UK), El</td>
</tr>
<tr>
<td>however there are likely more commercial activities and larger industrial demands.</td>
<td>Hierro, Canary Islands (ES), Miyakojima Island (JP),</td>
</tr>
<tr>
<td>Solar is a main resource with large potential for heating water and meeting electric</td>
<td>Guadeloupe (FRA), Martinique (FRA), Mayotte (FRA),</td>
</tr>
<tr>
<td>demand. The systems will have strong potential for wind, and, if available</td>
<td>Reunion Island (FRA), Curacao (NL),</td>
</tr>
<tr>
<td>geothermal development. Biomass and hydro resources should be considered if local</td>
<td></td>
</tr>
<tr>
<td>resources are available.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Category 5: Remote research stations</strong></td>
<td>Resolute Station, Nunavut (CAN), Research stations in</td>
</tr>
<tr>
<td>Climatic conditions differ considerably since research station locations are worldwide,</td>
<td>Antarctica, Island of Osmussaare (Estonia), Zackenberg</td>
</tr>
<tr>
<td>from arctic to tropical areas. Energy needs are heavily tied to the residential</td>
<td>Research Station, Greenland (DK), Rothera, British</td>
</tr>
<tr>
<td>demands for researchers. Research equipment needs may also drive demand for</td>
<td>Antarctic Survey (UK), Ross Island (Antarctica)</td>
</tr>
<tr>
<td>electricity. Transportation needs are limited – mostly for supply deliveries with</td>
<td></td>
</tr>
<tr>
<td>limited local transport needs. Resource availability will depend heavily on the site</td>
<td></td>
</tr>
<tr>
<td>location. Smaller research stations are stronger candidate for higher penetrations of</td>
<td></td>
</tr>
<tr>
<td>renewables than larger stations.</td>
<td></td>
</tr>
<tr>
<td>Main Characteristics</td>
<td>Example remote areas</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Category 6: Remote areas in developing countries</strong></td>
<td>Many regions of Africa (Kenya, Tanzania, Uganda, Zambia, Namibia, etc.), <strong>Akkan, Morocco</strong>, western China, Burma, Sri Lanka, certain parts of Central America.</td>
</tr>
</tbody>
</table>

Environmental conditions vary widely across the different developing country locations worldwide. Energy needs are often unmet, and there is a higher reliance on traditional energy methods (for example, cow dung and wood for cooking or candles for lighting). Many developing countries will have no or limited existing access to electricity in remote areas. Energy demand will be significantly lower than the other categories, although there is a higher potential for load growth. Solar is often an abundant and viable energy source. If available, hydro will be one of the most inexpensive solutions, and there may be some potential for wind and biomass technologies. There is still debate on appropriate development pathway for these areas, although approaches that are community-initiated and inclusive have proven most successful.
Table 2 below provides a high-level summary of the specific considerations as they relate to each category. The results presented are a general summary to provide a starting point for engaging with each of the remote areas; individual remote locations within a category may vary. The table covers a range of considerations. The energy needs specifies how much demand there will be for each energy type, the resource availability summarizes the expected renewable resource availability, the access challenge summarizes the expected difficulty of transportation access to the remote area, the climate specifies the type of climate that can be expected throughout the year, and the demand type breaks down the typical split along expected energy consumer types. Each of the areas may also be expected to differ in the availability of governance infrastructure and the expected levels of energy poverty. The table also provides a summary of the short- to medium-term renewable penetration that can be expected, although in the longer term it is expected that 100% renewable will be possible.

| Table 2: Summary of applicability of considerations to each drawn from the case studies |
|---------------------------------|------------|------------|-------------|-------------|-------------|
| Energy Needs                    | Cold       | Temperate  | Small Warm  | Large Warm  | Research stations |
| Heating                         | ★★★       | ★★         | ¶           | ¶           | ¶           |
| Cooling                         | ★          | ★☆         | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
| Electricity                     | ★★★       | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ★☆☆☆       |
| Internal Transport              | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     |
| Resources Availability          | Solar      | ★★         | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
|                                | Wind       | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
|                                | Hydro      | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
|                                | Geothermal | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
|                                | Biomass    | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
| Access Challenge (external transport) | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     |
| Climate                         | Cold       | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
|                                | Hot        | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
| Demand Type                     | Residential| ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ★☆☆☆       |
|                                | Commercial | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
|                                | Industrial | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
|                                | Tourism    | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       | ¶           |
| Governance infrastructure      | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       |
| Energy poverty                  | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       |
| RET Electricity Penetration Rate feasible in the short-medium term | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       |
| RET Heat Penetration Rate feasible in the short-medium term | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       |
| RET Transport Penetration Rate feasible in the short-medium term | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆☆☆☆     | ★☆☆☆       |
In order to explore the different categories in greater detail, a series of representative case studies were developed. The case study locations are shown in Figure 9 below. Each of the case studies is then profiled in detail in Appendix A.

![Figure 9: Map of Case Studies around the World. Source: Own elaboration](image)

The distinction between small and large areas is based primarily on the size of the electricity grids. This report uses size categories derived from those proposed by Lundsager et al. (2001):

<table>
<thead>
<tr>
<th>Installed Power</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1kW</td>
<td>Microsystems</td>
<td>Single point DC-based</td>
</tr>
<tr>
<td>1 – 100 kW</td>
<td>Rural Microgrids</td>
<td>Small power system (DC and AC)</td>
</tr>
<tr>
<td>100 kW – 10MW</td>
<td>Island power systems</td>
<td>Isolated grid systems (AC)</td>
</tr>
<tr>
<td>&gt;10MW</td>
<td>Large power systems</td>
<td>Large remote power system (AC)</td>
</tr>
</tbody>
</table>

This report focuses primarily on community energy systems, and therefore does not explicitly consider the microsystem category (<1kW) as a system size differentiator. For simplicity, the middle two categories (rural micro-grids and island power systems) have been combined into a single “Small remote power systems” category. The majority of remote areas with long winters and remote areas with temperate climates have electricity systems that are 10 MW or below. There is greater size diversity in
areas with warm climates and so this report creates separate categories for small and large remote areas in warm climates.

The specific considerations contained in this section are intended as high-level overviews to orient policymakers to some of the issues that may need to be considered and are by no means comprehensive. Individual renewable energy resource assessments and customized energy scenario analyses should be completed for each remote area.

3.2.1 REMOTE AREAS WITH LONG WINTERS (CATEGORY 1)

3.2.1.1 ENVIRONMENTAL CONDITIONS

Remote areas with long winters are located both on islands and on mainland areas (e.g. northern Canada and interior Norway).

- The harsh winter environment can impact both energy demand (see below) and the security of energy supplies. The long winter season, for example, can cause some passageways to be blocked by ice, limiting access to the community during several months of the year. In a related problem, low water levels have also proved challenging in some areas in northern Canada during the summer months, as diesel is typically delivered by barge. The increasingly unpredictable freeze-thaw cycle has also created some challenges, as roads that have been used seasonally for years can become impassable during certain times of the year. Ensuring that sufficient fuel is available for heating can be a matter of survival for many community members. As a result, these communities typically rely heavily on large diesel storage facilities. The challenges can be even more acute for communities such as Baker Lake in Nunavut, which is the only community in Nunavut that is entirely landlocked. As a result, it relies entirely on air delivery for everything that enters the community, ranging from diesel, gasoline, food supplies, and materials.

- Depending on how far north the community is, the freezing and thawing of areas previously under permafrost can require special strategies for ground-mounted renewable energy systems, storage tanks, pipelines, as well as power plants (Canadian Standards Association, 2010). Permafrost is a layer of soil (typically 1-4 m deep, but can also be far deeper) that remains frozen throughout the year. The thawing of previously frozen earth can cause increase installation costs such as the cost of foundations for wind turbines or the cost of wells for geothermal heat pumps (Baring-Gould and Corbus, 2007). It can also create problems for pipeline infrastructure, as seen in certain areas of Alaska.

- Northern communities typically have long daylight hours during the summer and short daylight hours during the winter. This can limit the number of hours during which operation and maintenance work can be undertaken, as well as the hours (and seasons) during which solar systems can generate energy. However, the long daylight hours from spring to fall can provide ideal conditions for domestic or commercial hot water systems, as well as remote PV applications.

---

23 For example, in early 2012 the city of Nome had a particularly cold winter, disrupting fuel supplies. The city did not get the last fuel delivery of the year before it iced up, and special icebreakers had to be used to deliver the fuel (Yardley, 2012)
Northern remote communities also typically have small populations (less than 5,000, and in many cases less than 500).

With global climate change, remote areas with long winters are likely to undergo significant changes. Northern latitudes are warming significantly faster than the rest of the world and changes are already evident. According to the most recent Arctic Report Card, the rapidly melting ice in the Arctic is the “new normal” (Richter-Menge et al., 2011). Vegetation is advancing northward while permafrost is melting.

The following sections are divided into three broad categories capturing the basic areas of energy needs in remote areas:

1. Thermal energy needs
2. Electricity needs
3. Transportation needs

Each of these subsections is considered in terms of the energy demand and infrastructure considerations, the primary resources available in this remote area category, as well as the unique considerations relevant to achieving high levels of renewable energy penetration in that area.

3.2.1.2 THERMAL ENERGY NEEDS

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Heat is the largest driver for energy demand in areas with long winters. Most of this heating load is allocated to space heating, a necessity throughout much of the year in order to ensure comfort and survival. For example, in the remote community of Cape Dorset in Nunavut, heating needs make up over two thirds (roughly 67%) of total energy needs (Brothers 2011). As a result of the high heat demand and risk of energy supply disruptions (e.g. from iced in ports or impassable roads or bridges), northern remote communities generally require comparatively large storage facilities for either diesel or fuel oil. The majority of heat is supplied by burning diesel fuel in oil furnaces, although a growing number of areas also rely on burning either cordwood, or wood pellets. The Northwest Territories has investigated increasing the use of wood pellets to provide heating in both residential and commercial applications ((Arctic Energy Alliance, 2009; BW McCloy & Associates, 2009)). Also, it is important to note that diesel-fired electricity systems can be configured to supply heat as a by-product captured from the engine cooling system or diesel exhaust. Approximately 27% of the remote diesel plants in Alaska, for example, are configured for cogeneration (MAFA and Northern Economics, 2004).

PRIMARY RESOURCES AVAILABLE

Biomass. The availability of biomass resources depends on the location of the remote community. In higher latitudes, little woody biomass grows. All of Nunavut in Canada, for example, is north of the tree line. In lower latitudes, many remote mainland communities have ample access to forested areas. Almost all of the biomass consumed in the Yukon in Canada, for example, is grown locally; slightly under
half of the biomass in the Northwest territories is locally sourced whereas the rest is imported (Northern Premiers’ Forum, 2011). Efforts are underway to boost this, primarily using wood pellets. The majority of the biomass in current use in Canada is either cordwood or wood chips, although wood pellet production and distribution is being explored.

**Solar thermal.** Communities with long winters can and have deployed solar water and air heating systems. A key consideration is that systems must use freeze protection strategies such as closed glycol loops with electric pumps, which increase system costs (Burch et al., 2005). Some communities such as Okotoks in Alberta (Canada) have explored the use of large-scale solar thermal storage using underground storage systems (DLSC 2012). Solar thermal energy is stored underground during the summer months and released slowly to a neighbourhood in Okotoks, AB (Sibbitt et al. 2011). The system currently provides 90% of the required winter heating load. While this system is installed in mid-latitudes (51.1° N), the deployment of similar systems in remote areas further north, as well as in other similar climates, could be expanded in the years ahead.

**Geothermal heat.** While direct geothermal heat is site specific, there are opportunities to harness it in certain northern remote areas. Geothermal heat pumps (GHPs), by contrast, can be installed throughout most communities. Note that ‘GHPs’ includes air-to-air, ground-source, as well as hydro-geothermal heat pump technologies. GHPs are typically sized for the cooling load. In northern areas, the capacity of the GHP is determined by the heating load of the building and the heat pump will likely be used primarily for heating (and not cooling). There are unknowns as to the long-term performance of GHPs in cold climates, such as stress on underground infrastructure in the presence of permafrost and the ability of soil to recover heat over time (Meyer et al., 2011). Geothermal may also be limited in areas with cold ground temperatures, such as the Laurentian Plateau bedrock in northern Canada. However, GHPs have been deployed widely in non-remote and cold climate areas of Nordic countries. In Sweden, for example, 30% of households utilize GHPs (Langniss et al., 2007). It is likely that GHPs could be successfully deployed in remote areas as well, although the deployment of the required drilling equipment and technical expertise may be a barrier.

**ACHIEVING HIGH PENETRATION SCENARIOS**

**Biomass** is the largest and most reliable source of renewable thermal energy internationally. It may be difficult for remote areas that lack a local biomass thermal resource to achieve 100% renewable heat without significant investment in alternative technologies and infrastructure, although there are examples of some high penetration initiatives such as the pilot projects such as in Okotoks mentioned above (DLSC 2012, Sibbitt et al. 2011). Geothermal heat pumps, for example, can be designed to supply a significant percentage of household heat. In Sweden, systems are sized to supply 90% of household thermal load, supported by an electrical back-up heater (Karlsson et al., 2003).

---

24 Old gold mining shafts in Yellowknife, Canada, for example have been filling with water warmed to 50°C by the Earth. It is estimated that this resource could provide up to 20 MW of heating capacity. The town of Whitehorse, Canada, currently uses geothermal water to keep its municipal pipes from freezing (Northern Premiers’ Forum, 2011).

25 Although certain areas may limit installations, broad areas of northern Canada can support GHPs and systems have been installed (e.g. Gray, 2006)
Solar space and water heating systems could also be deployed, although they need to be engineered against harsh conditions. The pathway to 100% renewable thermal energy in northern communities will rely heavily on energy efficiency. For existing buildings, it has been estimated that on average 60% can be saved through insulation, window replacements and ventilation systems with heat recovery mechanisms (Singer, 2011). For new construction, it is possible to construct buildings that require low or no heating systems through the use of passive design principles (e.g. passive houses) (Strom et al., 2006). There is an increasing number of passive houses in northern climates such as in Sweden and Norway (Janson, 2008). This points to the potential for improved (i.e. more stringent) building codes in northern climates, in conjunction with distributed thermal and district heating applications.

3.2.1.3 ELECTRICITY NEEDS

ELECTRICITY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Similar to demand for heat, electricity demand may also be seasonal depending on key industries such as fishing. Residential electricity and heating demand could decrease, for example, at times when the fishing fleet is at sea, whereas commercial / industrial electricity and heating demand could decrease when the fishing season ends. The seasonal availability of sunlight also means that lighting demand tends to increase significantly during the winter months and decrease during the summer months compared to southern regions. Also, unlike in warmer areas, tourism is not typically a driver of seasonal load variations.

PRIMARY RESOURCES AVAILABLE

Wind. The wind resource tends to be very strong in many areas with long winters. Wind turbines have been used throughout Canada and Alaska to power many remote communities. Special consideration needs to be given to prevent ice formation on wind turbine blades, which can lead to reduced performance and safety issues from thrown ice (Andersen et al., 2011; Morgan et al., 1998). This notwithstanding, many northern communities are beginning to explore the use of wind to capitalize on high average wind speeds in many locations (e.g. >7m/s).

PV. Annual insolation in northern climates can actually be better than in more southerly latitudes. The Gulf of Bothnia in the Baltic Sea near the Arctic Circle, for example, has a better solar resource than in Germany. PV systems can also function better in colder climate since heat can cause voltage drops. The use of photovoltaics can be challenging, however, because the resource can be unevenly distributed with long daylight hours in summer and short (or no) daylight hours in winter (Nordic Energy Research, 2010). As a result, PV output does not generate power when diesel demand is at its highest (i.e. in winter). Also, northern climates can pose challenges for solar PV due to heavy snowfall in the winter months, which can cover panels and decrease output.

Geothermal. As mentioned above, geothermal electricity is a highly site-specific resource. Some areas with long winters, such as Greenland, have only low temperature geothermal resources that are not capable of generating electricity, whereas others in Canada and Alaska have comparatively good

---

26 For more information about wind icing specifically, and recommendations for wind energy in cold climates in general, see the IEA’s Wind Energy in Cold Climates website: [http://arcticwind.vtt.fi/](http://arcticwind.vtt.fi/)
potential for geothermal electricity (Crimp et al., 2007). There are currently 95 MW of geothermal under development in Alaska, including a potential 10 MW project in the remote area of Unalaska (Jenniejohn, 2011). However, the potential for geothermal-based electricity generation is limited when compared to the availability of other RE sources.

Hydropower. Hydropower is widely available in some remote cold communities. Several cities in Greenland, for example, have developed their hydro resources at four sites totalling 68.4 MW. There are currently 130 MW of hydropower in the three northern Canadian territories, with approximately another 70 MW under development (Northern Premiers' Forum, 2011). An example of this is a recent proposal by Nunavut’s sole utility to develop its hydro resources outside of the Territory’s largest community, Iqaluit. Many northern communities, however, either do not have readily exploitable hydropower resources or only have access to them for part of the year when the resources are not frozen. A further concern in northern areas is the variability in water flow from one year to the next, which can be more pronounced than in temperate climates.

ACHEIVING HIGH PENETRATION SCENARIOS

It is likely that high penetration renewable electricity scenarios in remote northern communities will rely primarily on wind given its availability and proven ability to integrate into hybrid networks with diesel generators and with hydrogen storage technologies (Brothers 2011). Many low penetration wind/diesel hybrids have already been successfully demonstrated, and many of these communities are now transitioning to higher levels of renewable electricity penetration (i.e. 50% plus). Achieving higher penetrations of renewables is theoretically possible, but would require the presence of firm, dispatchable renewables such as biomass, biodiesel, hydropower, or the calculated deployment of storage technologies. As discussed above, not all remote communities have ready access to these resources. Another consideration is that electricity generators may displace diesel generation that also supplies heat (i.e. as a CHP system) and additional heat sources will need to be identified in such cases (Baring-Gould and Corbus, 2007). A key factor in high penetration scenarios, in the north as in elsewhere, is the extensive deployment of energy efficiency.

3.2.1.4 TRANSPORTATION NEEDS

DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Many communities in remote areas with long winters lack connection to extensive road networks, with some exceptions such as ice roads in parts of Canada and roads to remote areas in the interior of Norway. As a result, automobile and truck traffic is limited primarily to short and local trips. In many areas, off-road vehicles such as snowmobiles or four-wheelers (quads) are used extensively to supplement on-road transportation. Depending on the location of the community, a proportion of transportation fuel will be consumed either by boats or planes for supplies and fuel deliveries. Also, a major source of transportation demand in many northern communities is the trucking required for water/wastewater systems. In Cape Dorset in Nunavut, ground transportation makes up roughly 8% of

See http://www.aluminium.gl/en/
energy needs, with a further 2% used in the form of jet fuel (Brothers 2011). For communities that depend heavily on fishing, there will also be high seasonal demand for fuel for the fishing fleets.

**PRIMARY RESOURCES AVAILABLE**

**Biofuels.** There is little opportunity for the cultivation of the current generation of plant-based biofuels (e.g. ethanol or biodiesel) in remote communities with long winters. Waste cooking oil may also be available in certain communities, if rationed appropriately. In fishing communities, there have been early experiments with using fish oil for biodiesel, but challenges remain with how best to process the fuel for use (Witmer, 2010). Biodiesel also has a comparatively high freezing point compared to conventional diesel, which makes its use more complicated in cold climates, especially when trip distances are short and the engine is frequently off (National Biodiesel Board, 2007). However, recent advances in biodiesel technology have led to the development of low-temperature biodiesels that could be feasible in northern communities. However, as with conventional diesel, such fuels will likely have to be imported, which does not directly advance energy security.

**Electric vehicles.** Electric vehicles powered by renewable electricity could potentially be deployed in remote areas with long winters. Several cities in Greenland, for example, currently produce surplus electricity from hydropower which is used to heat water for district heating systems; this excess electricity could be utilized to charge electric vehicles (COWI A/S, 2009). A similar approach could be adopted using excess wind power generation. However, the performance of current lithium-ion automobile battery technologies does decline in colder climates.

**ACHIEVING HIGH PENETRATION SCENARIOS**

The achievement of high penetrations of renewables in the transportation sector would be challenging in the near term in northern communities given current technologies. A recent roadmap for renewable transportation in Greenland, for example, concluded that hydro-powered electric vehicles could meet a significant proportion of national on-shore transportation demand. Biofuels were considered a secondary fuel source because biofuels need to be imported and because their quantity may be limited in the future based on competing demands on biomass resources. A share of biofuels would likely be required, however, since not all communities are co-located with hydropower resources and because some transportation needs would require internal combustion engines. Greenland’s fleet of boats would also likely require imported biofuels or else hydrogen produced from renewable electricity. Powering the Greenland fleet with hydrogen would require twice as much electricity generation as currently installed in the country and it would take a significant expansion in hydropower resources to meet this demand (COWI A/S, 2009). This example serves to show that, while not insurmountable, the challenges of achieving a high level of renewable energy in the transportation sector are significant.

**3.2.1.5 OTHER CONSIDERATIONS**

In addition to the technical considerations listed above, it is important to note that some remote communities in areas with long winters place a heavy emphasis on traditional or subsistence hunting. In such circumstances, an informal economy of barter and trade may exist in parallel with a formal cash-
based economy. Residents in such dual economies are likely to have limited resources with which to secure financing for renewable energy systems. This is likely to require external governmental support.

### 3.2.1.6 CASE STUDIES

**KODIAK ISLAND, ALASKA, USA**

A case study on the Pillar Mountain Wind Farm in Kodiak, Alaska, was completed to illustrate the successful implementation of renewable energy in remote areas with long winters.

The Pillar Mountain Wind Farm is a wind/diesel hybrid system completed in 2009 on the island of Kodiak, Alaska. The system is composed of three 1.5 MW wind turbines and 33MW of diesel generator capacity integrated with an existing 20 MW hydropower dam. Since its completion, the project has been seen as a success, reducing diesel consumption by 3.4 million liters and saving the utility US $2.3 Million (€1.75 Million) during its first year of operation. An additional 4.5 MW of wind power generation is scheduled to come online by 2012, followed shortly by a pumped hydro storage project. Together, these investments are expected to provide 98% of the island’s electricity from renewable sources.

**RAMEA, NEWFOUNDLAND AND LABRADOR, CANADA**

A case study of Ramea Island is included to provide an example of an innovative hybrid system that makes use of wind power and a hydrogen storage system in combination with diesel generators to supply local loads on the island. The site now includes 690kW of wind power, a 250kW hydrogen generator, and three different diesel units. The project was the product of a joint collaboration between Natural Resources Canada (NRCan), Frontier Power Systems, Nalcor Energy, as well as the Wind Energy Institute of Canada (WEICan) among others (see Appendix A).

### 3.2.2 REMOTE AREAS WITH TEMPERATE CLIMATES (CATEGORY 2)

#### 3.2.2.1 ENVIRONMENTAL CONDITIONS

Remote areas in temperate regions are not typically prone to environmental extremes like remote areas with long winters or remote areas in warm climates (e.g. hurricanes and heat waves). However, the need for both heating and cooling services at different times of the year may require additional capital investment. The population size of remote areas in temperate climates varies significantly, from less than 100 in the case of small islands, to thousands in the case of larger regions.

The following sections are divided into three broad categories capturing the basic areas of energy needs in remote areas:

- Thermal energy needs
- Electricity needs
- Transportation needs

Each of these subsections is considered in terms of the **energy demand and infrastructure considerations**, the **primary resources available** in this remote area category, as well as the unique considerations relevant to **achieving high levels of renewable energy penetration** in that area.
3.2.2.2 THERMAL ENERGY Needs

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS
Thermal demand is a significant factor in temperate areas and comprises a significant share of total energy use, particularly in areas where energy demand is primarily driven by the building sector. Thermal demand is lower, however, than in areas with long winters. Also, temperate areas also do not face the same fuel supply disruption risks from extreme winter weather.

PRIMARY RESOURCES AVAILABLE

Biomass. Certain remote areas in temperate areas have adequate woody biomass resources to support local biomass. Many remote communities in Labrador, for instance, rely heavily on wood to supply their heating needs. To the extent that municipal waste is considered “renewable” it may be used to supply thermal energy. In the Faroe Islands, for example, municipal solid waste is used to generate both heat for district energy as well as to dry fish for export (Mikladal, 2005). Few communities in temperate areas have sufficient land area to cultivate biofuels.

Solar thermal. Solar thermal systems can provide a significant proportion of both water heating and space heating demand in temperate areas, given the comparatively greater amount of sun year round than in higher latitudes and the comparatively warmer temperatures. As with colder climates, winters in temperate areas will require solar water heating systems to be equipped with closed loop or drain-back systems to prevent freezing.

Geothermal energy. Geothermal heat pumps in temperate climates can be configured to provide both heating during the winter and cooling during the summer. This makes them an important component of sustainable energy strategy in temperate regions to reduce reliance on imported fuels and energy. This can include a focus on either aero-geothermal, hydro-geothermal, or ground-source geothermal heat pumps.

ACHIEVING HIGH PENETRATION SCENARIOS
Temperate climates will generally be better positioned than climates with long winters to achieve 100% renewable energy penetrations in the heating sector because heating loads are not as high. Moreover, the availability of sunlight during winter allows for solar thermal to player a more active role in year-round provision of heat. In general, temperate regions are better positioned to rely on a diversity of thermal energy supply sources, whether for heating or for cooling needs.

3.2.2.3 ELECTRICITY Needs

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS
As in remote areas with long winters, electricity and thermal demand may vary seasonally if the community has an active fishing industry. Temperate areas with tourism industries may also see seasonal demand for electricity spike in the summer. This can create an ‘under-utilized capacity’ problem, where infrastructure must be over-built in order to accommodate high seasonal peaks caused by tourism.
 PRIMARY RESOURCES AVAILABLE

Wind. Although site specific, there is generally good wind availability in temperate remote areas since many are primarily coastal areas or islands. Freezing and icing issues are also less severe in temperate regions.

Solar energy. There is a relatively universal solar resource in temperate areas as well, without the extreme seasonal variation found in remote areas with long winters.

Geothermal. Geothermal electricity is site specific and it is likely that systems in temperate climates will need to be small, given the small capacities of most temperate island grids. Hachijojima Island in Japan, for example, installed a 3.3 MW condensing flash geothermal system in 1999 with electricity costs at approximately $0.20/kWh (€0.15/kWh). Although this is a significantly higher levelised cost of energy than the larger geothermal plants on Japan’s main islands, the rate was attractive since the displaced electricity was previously supplied by diesel generators (J. W. Lund and Boyd, 1999).

Hydropower. Temperate climates can secure access to year round hydropower facilities, depending on rainfall, elevation, topography, and other factors. The Faroe Islands, for example, have four small-scale hydropower stations each under 10 MW (Mikladal, 2005). Since most temperate remote areas are islands, there may be possibilities for seawater pumped storage if land-based hydro is not available. In Okinawa, for example, the 30 MW Yanbaru pumped seawater storage facility has successfully been used to balance power on the island (Fujihara et al., 1998).

Ocean energy. Another source of electricity for remote temperate areas is ocean energy. Electricity from the oceans can be generated in a host of different ways, including wave power, tidal power, and salt-gradient flow technologies. Also, the ocean can be used in many areas as part of a hydro-geothermal system, which can be used to heat or cool buildings. In tropical and subtropical areas, ocean cooling could provide an alternative to expensive air conditioning systems.

ACHIEVING HIGH PENETRATION SCENARIOS

Higher penetrations of electricity may also be more possible in temperate areas than in areas with long winters. This is partly because temperate areas have lower overall heating loads, but perhaps more importantly because they have a wider variety of electricity supply options available to them. This means that they can diversify their supply source, including on-shore and offshore, as well as baseload and intermittent. A related factor is that temperate areas are generally able to more effectively harness sources like PV and hydro year-round, serving to mitigate heating peaks in the winter, and air conditioning peaks in the summer.

3.2.2.4 TRANSPORTATION NEEDS

The majority of remote areas in temperate areas are islands since most settled mainland areas in temperate regions are connected to central electricity infrastructure. Moreover, temperate remote areas tend to be comparatively small. As a result, the most significant transportation energy demand is

---

29 There are exceptions to this. Remote forestry operations in British Columbia, for example, could be considered temperate climates.
from air (i.e. jet fuel) and maritime transportation related to fishing, supply and transportation to and from mainland areas.

**PRIMARY RESOURCES AVAILABLE**

The transportation options in temperate areas are similar to those in areas with long winters. There is limited availability of local biofuels, aside from fats, oils, and greases from waste stream such as cooking or fish processing. In the near term, policymakers will need to weigh whether to import biofuels from other areas for land-based travel. In the mid- to long-term, there will be opportunities to develop electric land-based vehicles and hydrogen systems for boats and policymakers can pursue strategies in the near-term to position remote areas for these opportunities. Electric vehicles in particular may provide a valuable option for land-based transport needs.

**ACHEIVING HIGH PENETRATION SCENARIOS**

The achievement of higher penetrations of renewable energy in transportation fuels will depend on variables similar to those in remote areas with long winters, including the ability and willingness to import biofuels, and the speed with which electric and hydrogen vehicles are developed globally and are made available to remote communities.

**3.2.2.5 CASE STUDIES**

**ISLE OF EIGG, SCOTLAND**

Prior to 2008, there was no grid electricity on the Isle of Eigg. Households used their own diesel generators and generally only had access to a few hours of electricity a day. Studies were undertaken to determine the feasibility of connecting the island to the mainland grid of Scotland, but those proposals were abandoned due to the high costs. In 2004, a hybrid renewable energy system was proposed, with a total price tag of £1.6M (€1.87M). Completed in 2008, the system included a 10 kW PV system, 112 kW of hydro capacity, a 24 kW wind farm, and 160 kW of diesel backup capacity. This system now provides up to 5 kW of electricity for households and 10 kW of electricity for businesses 24 hours a day, at 25 – 40% of the cost of what they used to pay for diesel.

**FAROE ISLANDS, DENMARK**

Separate from mainland Denmark, the Faroe Islands have relied heavily on diesel fuel for energy production. In 2009, fossil fuels met 95% of demand, with only a 4% share of renewable energy. In response, the Faroe Islands are currently developing a diversified agenda of projects and initiatives that are seeking to increase the use of wind, solar, and hydro technologies to displace fossil-based generation.
3.2.3 SMALL WARM REMOTE AREAS (CATEGORY 3)

3.2.3.1 ENVIRONMENTAL CONDITIONS

The majority of small warm remote areas in the IEA-RETD countries are islands. Most mainland warm remote areas in IEA-RETD and OECD areas are connected to central electricity grid infrastructure if inhabited.\(^{30}\)

- Many small warm remote areas are vulnerable to hurricanes, typhoons and other catastrophic weather events. Extreme weather events are likely to increase in severity as the climate changes, which will increase the need for standards and codes that support resilient construction of energy and non-energy infrastructure.
- Flooding and inundation. Small remote areas are also on the frontlines of risk from sea-level rise and flooding. Internationally, small tropical areas are expected to bear a disproportionately large burden of climate change risks. The island of Tokelau, for example, has almost completed a plan to switch from 100% diesel to 90% solar electricity by 2012. While this will put Tokelau in a leadership position in terms of high-penetration scenarios, Tokelau’s elevation is one meter above sea-level and so it will also be the first Pacific island to be inundated if sea levels rise (Toloa, 2011).
- Population levels in small remote areas in warm climates typically range from a few hundred in the case of many Pacific islands, to a few thousand in case of islands in the Bahamas, or certain smaller islands of Hawaii.

The following sections are divided into three broad categories capturing the basic areas of energy needs in remote areas:

- Thermal energy needs
- Electricity needs
- Transportation needs

Each of these subsections is considered in terms of the energy demand and infrastructure considerations, the primary resources available in this remote area category, as well as the unique considerations relevant to achieving high levels of renewable energy penetration in that area.

3.2.3.2 THERMAL ENERGY NEEDS

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Demand for thermal energy in small warm remote areas is comparatively low on a per capita basis and is primarily driven by water heating (often propane). There can be significant seasonal demand for heating, however, that corresponds with the tourist season. In the Caribbean, for example, winter months in higher latitudes are the high season for tourism, whereas summer is the low season. In the Pacific, by contrast, tourism may vary according to whether it is the wet or dry season.

\(^{30}\) An exception to this is certain communities in the Outback of Australia, which rely on stand-alone or mini-grid systems for electricity.
PRIMARY RESOURCES AVAILABLE

**Biomass.** Larger remote warm areas can have sufficient land area and/or agricultural sectors to support the production of biomass for thermal energy or power. Small remote warm areas, however, typically do not capture biomass for thermal applications.

**Solar thermal.** Solar thermal systems can be widely and readily deployed in warm remote areas. Unlike cold and temperate climates, warm climates do not require freeze protection systems. Warm climates can also make use of systems with integrated tanks and collectors and thermo-siphon systems that do not require pumps to circulate water. As a result, solar thermal systems in warm areas are generally less expensive to install and operate. Solar thermal systems are already installed at significant penetration levels in some remote areas, such as Barbados. However, in many other warm islands in the Caribbean, the South Pacific and the Indian Ocean, solar thermal systems are virtually absent. This underscores a situation where significant, low-cost RE potential has yet to be developed.

**Geothermal.** Geothermal heat pumps in warm remote areas would be configured primarily to supply cooling, rather than heating. Geothermal heat pumps can be widely distributed in warm remote areas. In particular, hydro-geothermal technologies that draw on the ocean’s cooler water can be used to provide a form of district cooling. Unfortunately, data on geothermal heat pumps in warm remote areas is limited. What little data is available appears to indicate that they are not widespread in the Pacific or the Caribbean. The Caribbean islands, for example, have installed only 100 kW. In the Pacific, Papua New Guinea also has 100 kW of capacity, whereas the Philippines has 3 MW. These figures are small in comparison to the 50,000 MW of capacity installed globally (J. W. Lund et al., 2010).

ACHIEVING HIGH PENETRATION SCENARIOS

The heat load in warm remote areas is primarily water heating. Solar engineers, however, typically recommend that solar water heating systems be sized to meet 40 to 70% of annual heating load. Sizing a system to meet 100% of annual demand will result in high temperature water being produced in summer time when it is less needed and may be problematic for the system (Bickford, 2007). If policymakers pursue renewable electricity aggressively, then it could be possible to utilize solar thermal to the greatest practical extent and make up the remainder of thermal energy demand using electric heating.

3.2.3.3 ELECTRICITY NEEDS

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Grids in small warm areas without tourists can have fairly high peaks since grids are small and loads are relatively disaggregated. The electricity demand may also vary significantly on a seasonal basis due to the influx of tourists. Tourist demand for air conditioning, for example, can be a significant driver for local demand. The island of Saba, for instance, has a population of 2,000 people but receives an estimated 25,000 visitors every year. Air conditioning demand is also on the rise from local residents who historically have had lower levels of air conditioning usage. Many households also utilize electric shower heaters that attach directly to showerheads. These systems are cheap but inefficient and contribute to morning peaks. In areas with significant fluctuations due to the tourist season, the electricity system is likely to require significant excess capacity. Where this is the case, alternative uses for excess electricity
could be developed (e.g. desalination of water, or the production of hydrogen for storage and transportation purposes).

**PRIMARY RESOURCES AVAILABLE**

**Wind.** Wind availability in warm remote areas depends on location. Some warm remote areas, such as the Eastern Caribbean, for example, enjoy relatively consistent trade winds, whereas the western Caribbean has lower wind regimes. Coastal sites in the eastern Caribbean have diurnal variations in wind speed, with steady winds between 9 AM and 4 PM (Wright, 2001). This is unlike colder areas of the world where wind blows primarily at night. The availability of wind during the day has the potential to match daily demand.

**Solar.** Warm remote areas have the best solar resources of the categories considered in this study. PV is broadly available with comparatively steady seasonal availability. Unlike in cold and temperate remote areas, there may also be areas in warm remote areas that receive sufficient direct sunlight for solar thermal electric systems. A 2 MW solar thermal electric system, for example, was recently installed in the Kona desert in Hawaii.

**Geothermal.** Geothermal electricity systems tend to have high fixed costs, related to the costly and risky process of identifying an adequate geothermal resource. As a result, small geothermal systems such as the ones that would be scaled for small remote areas are costlier and more difficult to finance. There are some geothermal resources that overlap with small warm remote areas, but there have been few projects developed to date.

**Biomass.** As with biomass for thermal, there may be limited applications for biomass power in small warm remote areas unless there are locally available fuel or waste streams. In the Pacific, for example, the availability of coconut oil could provide a significant resource for small generators. A recent study, for example, estimated that coconut oil could meet up to 60% of energy demand for the smaller islands (Dimpl, 2011).

**ACHIEVING HIGH PENETRATION SCENARIOS**

Small warm remote areas are good candidates for supplying 100% of electrical demand from renewable sources, given their comparatively small grid sizes and the potential for a broad portfolio of available resources. In areas without high tourism, passive solar construction can minimize heat gain and lower air-conditioning load, whereas limited use of high power electrical appliances may help control peak electric loads (e.g. irons, hair dryers, drying machines, blenders, rice cookers, electric kitchens, microwave ovens, among others).

The tourism industry, however, may complicate attempts to contain energy use. Commercial hotel owners, for example, typically utilize very short payback criteria (i.e. 1 year or less) when evaluating investment decisions. This could present a significant barrier to the electrical energy efficiency measures that would enable higher penetration scenarios. Integrating higher penetrations of renewable power into small grids in remote areas can involve the use of excess power to serve deferrable loads such as ice-making, pumping water, and water desalinization.
3.2.3.4 TRANSPORTATION NEEDS

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS
The transportation demand of small warm remote areas is similar to that of the transportation demand of cold and temperate zones in that road travel is comparatively limited. In contrast to these areas, however, the use of motorcycles, mopeds, and bicycles is more widespread. Air and sea transport typically provide the primary means of obtaining supplies and engaging in international travel. Moreover, transportation demand tends to be seasonal, depending on whether there is a fishing industry of significant size, and depending on the size of the tourism industry. Islands with a significant tourism industry like Fiji, the Seychelles, Bali and a number of Caribbean islands experience a large jump in diesel demand in particular during these periods. In many small remote areas, the greater availability of bicycles could help in reducing diesel demand, and increase the access to transportation for many low-income residents.

PRIMARY RESOURCES AVAILABLE
Biofuels. The availability of biofuels in warm remote areas will depend on geographic location, as well as factors such as the presence of arable land or useful waste streams. The Caribbean, for example, has no biodiesel resources, but some countries do grow crops like sugar and cassava which could be used for ethanol production (Ludena et al., 2007). Pacific islands, meanwhile, have a strong available coconut oil resource and the potential for ethanol production. In total, it is estimated that 30% of regional transport could be replaced with biofuels if dormant plantations were revived and active industries were restructured (Cloin et al., 2007). However, concerns remain over the conflict of biofuel crops with the broader issue land availability, and food supply, concerns that are all the more acute on islands.

ACHIEVING HIGH PENETRATION SCENARIOS
Depending on available local and regional resources, it may be possible for small remote areas to move toward biofuels for transportation in the near term. If policymakers choose to import biofuels, there may be better regional availability than in remote areas with long winters depending on the region in which the remote area is located. Although there are currently no biodiesel resources in the Caribbean, there is sufficient regional soybean, sunflower, and palm production to supply 11% of regional diesel demand. There is also significant existing ethanol in Brazil, and potential to expand production in other countries. As discussed above, there is also significant potential to expand biofuels on Pacific islands. Over the longer term, however, warm remote islands are expected to face many of the same constraints faced globally related to the most appropriate uses of biomass and the limits of biomass sustainability. As with other areas, electric vehicles may be a practical alternative to biofuels. The Island-E car, for example, has been developed by entrepreneurs in Bermuda specifically to serve the needs of remote island communities.31 Models like these, or Paris’ recent electric vehicle rental scheme,32 could be deployed

31 See http://islandecar.com/E-CAR.html
32 See http://www.paris.fr/autolib
more widely in the near-term on small, remote islands, enabling them to reduce reliance on imported fuels while transitioning to a greater share of renewable energy in the overall mix.

3.2.3.5 CASE STUDIES

Two case studies were completed to provide illustrative examples of renewable energy projects in small warm remote areas: the solar PV hybrid project on the Island of Floreana, Ecuador, and the wind hybrid project on the Island of Coral Bay in Western Australia.

FLOREANA, GALAPAGOS ISLANDS, ECUADOR

The Island of Floreana is the smallest island in the Galapagos Archipelago, with 55 households and a population of 200. Prior to the implementation of the PV/Diesel hybrid project, a diesel generator operated for 13 hours a day in the main village on the island. Any households outside of the village had no energy access. The hybrid system, completed in 2003 and updated, included a multi-use solar grid for the village and five standalone PV facilities for farmhouses outside of the main village. An energy efficiency program was also enacted to provide rebates for energy efficient appliance upgrades.

CORAL BAY, WESTERN AUSTRALIA

In 2007, the Island of Coral Bay commissioned a 3 MW off-grid wind and diesel hybrid system to provide electricity for the 140 residents and 3600 daily tourists. The wind turbines from the project contribute on average 40-60% of the island’s power, although at times they can contribute up to 90% of the instantaneous power. Due to the existing subsidized electricity rates, the project required a 50% federal government capital subsidy for the project to be commercially viable. No extensions are planned at this time.

3.2.4 LARGE WARM REMOTE AREAS (CATEGORY 4)

The specific considerations for large warm remote areas are in many respects similar to the considerations of small warm remote areas. This section focuses primarily on major differences. One of the significant differences is the size of the population, which tends to be significantly larger, ranging from a several thousand to hundreds of thousands.

3.2.4.1 ENVIRONMENTAL CONDITIONS

The majority of large warm remote areas in the IEA-RETD countries are also islands, and they face many of the same environmental conditions that small warm remote areas do.

As with the previous sections, the following is divided into three broad categories in order to capture the basic energy needs in remote areas:

Thermal energy needs
Electricity needs
Transportation needs
Each of these subsections is considered in terms of the energy demand and infrastructure considerations, the primary resources available in this remote area category, as well as the unique considerations relevant to achieving high levels of renewable energy penetration in that area.

### 3.2.4.2 THERMAL ENERGY NEEDS

#### ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Thermal demand in large warm remote areas will be similar to thermal demand in small remote areas in that it may primarily be driven by the need for water heating and seasonally impacted by tourism. A key difference, however, is that large warm remote areas may also have larger-scale industrial, commercial, and agricultural operations that will require thermal energy to drive manufacturing processes or dry crops and lumber.

#### PRIMARY RESOURCES AVAILABLE

**Biomass.** The distinguishing characteristic for biomass in large warm remote areas is that such regions may have larger land availability that could be used to cultivate energy crops and larger existing agricultural production whose products or by-products could be used to generate thermal energy (e.g. bagasse).

**Solar thermal.** Commercial and industrial processes on large remote areas may require higher temperature heat than could be supplied by conventional solar water heating systems. The climate in warm areas may be conducive to the use of concentrated solar power. It is also possible to use concentrated solar thermal systems to generate high-temperature heat for use in industrial processes, rather than for use in electricity power plants (Weiss, 2006).

**Geothermal energy.** As with solar and biomass, large remote areas may be larger commercial and industrial thermal loads that geothermal heat could be utilized to serve. Heat pumps could also be used in hotels and other applications to supply cooling needs.

**Ocean energy.** Large remote islands may have abundant access to ocean energy sources, either thermal or for electricity generation. Moreover, ocean technologies may be better suited to larger remote regions, due to the presence of larger loads, and greater cooling or heating needs. Ocean energy technologies have not reach levels of maturity comparable to wind or solar technologies and have not been widely deployed globally.

#### ACHIEVING HIGH PENETRATION SCENARIOS

The potential for high renewable thermal energy penetration in large warm areas will be similar to small areas, although the potential for larger and higher-temperature commercial or industrial loads mentioned above might make 100% scenarios more challenging. On the other hand, larger islands make economies of scale possible in the development of certain thermal projects such as district cooling.

### 3.2.4.3 ELECTRICITY NEEDS
ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Electricity demand in large warm remote areas is naturally larger in magnitude than in small areas. The island of Guadeloupe, for example has a peak load of approximately 200 MW, whereas the island of Saba has only a 2 MW demand. Electricity demand may be potentially driven by a broader range of commercial and industrial activities than in smaller areas, such as air conditioning demand for commercial space (which may shift peaks towards midday) and electricity demand for large-scale desalination plants.

PRIMARY RESOURCES AVAILABLE

Wind. The primary difference between large and small areas is that large remote areas will not only have larger electricity loads that would require larger-scale turbines, but may also have the logistics and construction infrastructure necessary to install larger-scale systems. Larger islands are also likely to offer greater siting flexibility.

Geothermal. Larger remote areas can install larger geothermal systems and unlock the associated economies of scale. Many of the Caribbean islands are volcanic and have significant potential geothermal electricity resources (Huttrrer, 1999; Joseph, 2008), and countries such as St. Kitts and Nevis and Dominica are moving forward with projects that would generate the majority of national electricity from geothermal resources (Holm et al., 2010). Although geothermal potential in the Pacific is more limited than in the Caribbean, there are resources which could be developed in Papua New Guinea and Fiji among others (Ásmundsson, 2008).

Hydropower. There may also be greater potential for hydropower in larger remote areas, particularly those that are mountainous and that have high annual precipitation, such as Dominica. Also, larger islands with a high percentage of forest cover tend to have greater annual rainfall, and less sedimentation, both of which translate into better hydroelectric potential.

ACHIEVING HIGH PENETRATION SCENARIOS

It is more difficult to achieve 100% renewable electricity in large warm remote areas without significant geothermal or hydropower resources to provide baseload power. The reason for this that electricity demand on large warm remote areas is significantly higher than on smaller areas and the integration challenges may be more complex. Larger baseload generators operating on fossil fuels, for example, may not be flexible enough to follow renewable electricity, unlike smaller diesel generators. Similarly, larger storage systems such as large and centralized sodium sulphur (NaS) batteries or pumped hydro systems may be required for high-penetration scenarios and such systems introduce additional complexity, cost, and siting challenges. Several of the case studies deal with the potential of integrating advanced storage options, such as Reunion, and Miyakojima (see Appendix A).

3.2.4.4 TRANSPORTATION NEEDS

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Land-based transportation demand will typically larger in larger remote warm areas than in smaller remote areas. There are typically well-established road networks in large warm remote areas and higher
numbers of vehicle miles travelled per capita than in small remote areas because of the larger distances. As a result, larger islands tend to have a greater need for ground transportation.

PRIMARY RESOURCES AVAILABLE

Biofuels. As with thermal biomass, there may be greater potential for biofuels on large remote areas both because of larger available land area and the potential for fuel stocks from either agriculture (e.g. sugar cane for ethanol) or commercial wastes. If there is sufficient waste cooking oil available from commercial food establishments, for example, it can be collected and processed into biodiesel in centralized plants. In 2011, for example, Bahamas Waste Ltd. opened a commercial biodiesel processing facility for waste cooking oil on the island (Oberst, 2011). Such facilities could also accept waste cooking oil from cruise ships if cruise tourism traffic is sufficient and the ships are not recycling the waste oil for their own uses.

ACHIEVING HIGH PENETRATION SCENARIOS

The considerations for high-penetration renewable energy scenarios in transportation are similar to those in small warm areas, although large remote areas may at once have higher land-based transportation demand and greater potential for local biodiesel supply. Larger islands may be better candidates for developing electric vehicle infrastructure, partly due to economies of scale, and partly due to the presence of a greater number of potential buyers, or users. Moreover, their size makes them well suited to the current range of electric vehicles on the market. A good example of this is found on Reunion Island, which has begun laying the groundwork to enable the full electrification of the vehicle fleet on the island by 2030.

3.2.4.5 CASE STUDIES

BONAIRE, THE NETHERLANDS

The island of Bonaire, an overseas territory of the Kingdom of the Netherlands, has a population of 14,500 and a land area of almost 300km². In 2004, Bonaire’s only power plant burned down, which encouraged the island to rethink its long-term energy strategy and begin moving towards a 100% renewable electricity supply. The project was installed in 2 phases, with a 3rd phase at the planning and research and development (R&D) phase. In 2007, the first phase was completed with the installation of a 330 kW wind turbine. Phase 2 brought an additional 10.8 MW wind farm, a 14 MW diesel system, and 3 MW of battery storage. The batteries provide back-up power, provide 2 minutes of 3MW bridge time so that diesels can start if wind turbine output falls. The storage also provides a short-term dump load during system faults.

EL HIERRO, SPAIN

El Hierro Island is the smallest of the Canary Islands Archipelago, and is completely dependent on imported fossil fuels. In 1997 the local government developed its strategy to make the island energy self-sufficient as part of its Sustainability Plan. Twelve years later, the local government commissioned a hydro-wind/diesel hybrid system to provide the island with electricity from 100% renewable sources. The project is currently under construction and is expected to be operational by the first half of 2012. In
the longer term, electric vehicles are to be incorporated in order for the island to become fully independent from fossil-fuel imports.

MIYAKOJIMA, JAPAN

The island of Miyakojima is located in the Philippine Sea off the southwest coast of Japan, and is the largest of the Miyako islands. It has been expanding the use of renewable energy sources since the early 1990s, with the introduction of solar PV systems. A number of wind turbines have also been added in the years since to further reduce diesel use, and efforts are being made to increase the use of ethanol to fuel a portion of the transport fleet. Miyakojima has also started making use of large sodium-sulfur (NaS) batteries (4MW), as well as smaller residential-scale lithium-ion (Li-ion) batteries to enhance grid stability. The project is utility-owned and led, and was financed by Okinawa Electric Power Company. The utility’s aims are to mitigate the impact of rising diesel costs on the costs of electric supply on the island, while contributing to emissions reductions.

REUNION ISLAND, FRANCE

Reunion Island is located in the southern part of the Indian Ocean, approximately 700km east of Madagascar. While the island itself is only 50km across on average, it has a population of over 800,000, with annual load growth of 4-5%. The French government selected Reunion as an ideal location to undertake a wide range of RE deployment and demonstration projects, as well as a suitable laboratory to test the large-scale use of electric vehicles. Projects range from ocean thermal and wave power to solar PV and small-to-medium scale hydro. In addition, it has recently launched the Millener project, which involves the use of advanced grid and load management technologies, including residential battery storage. Other forms of storage in use in Reunion to balance intermittent renewables include grid-scale (1MW) storage with NAS batteries, as well as a set of elevated hydro storage tanks to capture rainfall. Recent tenders on Reunion have also focused on the integration of storage solutions. The French government has established a goal of meeting 50% of the island’s electricity needs with RETs by 2020, and a further goal of 100% of all energy use by 2030.

3.2.5 REMOTE RESEARCH STATIONS (CATEGORY 5)

3.2.5.1 ENVIRONMENTAL CONDITIONS

Research stations are located in remote areas throughout the world, from cold climate stations in the Arctic and Antarctic regions to warm weather stations in the Caribbean and the Pacific. They typically house a small number of residents, which results in modest energy needs. This report focuses on

---

http://cmbc.ucsd.edu/Research/Resources_For_Researchers/research_stations/ provides a sampling of research stations worldwide.
research stations, but similar conclusions could also be drawn for certain national parks, military installations, and other remote institutional facilities.

Also, many research stations are generally located in pristine or protected environments, which put a premium on low-impact technologies. For instance, the importance of protecting these environments may also be a driver to switch to RETs to prevent damage from fuel spills and other environmental risks associated with diesel and other fossil fuels.

The following sections are divided into three broad categories capturing the basic areas of energy needs in remote research stations:

- Thermal energy needs
- Electricity needs
- Transportation needs

Each of these subsections is considered in terms of the energy demand and infrastructure considerations, the primary resources available in this remote area category, as well as the unique considerations relevant to achieving high levels of renewable energy penetration in that area.

### 3.2.5.2 THERMAL ENERGY NEEDS

**ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS**

Heat needs in cold climate stations will be driven, primarily, by the residential needs of visiting scientists and researchers. There may be isolated need for heat for research, but this will depend on the particular research being undertaken at the remote research station.

**PRIMARY RESOURCES AVAILABLE**

- **Biomass.** It is unlikely that biomass will be available at many remote research stations, with the exception of wood biomass in certain cases. However, there are few trees at most Arctic and Antarctic stations, and local biomass is unlikely to be harvestable if the research station is located near protected biodiversity areas.

- **Solar thermal.** Warmer research stations may be able to develop solar thermal water heaters as well as solar air heaters to provide heating or supplement existing heating systems.

- **Geothermal heat.** Direct geothermal heat is site specific, and, as noted in the remote areas with long winters category, there are opportunities to harness it in northern remote areas. However, the heating needs of a research station are small and may be unable to benefit substantially from this resource. It is likely that GHPs could be successfully deployed, although the deployment of the required drilling equipment and technical expertise may be a barrier given the environmental sensitivity of the regions surrounding most remote research stations. Permafrost at Arctic and Antarctic stations may also provide a barrier to GHPs.
ACHIEVING HIGH PENETRATION SCENARIOS

The pathway to 100% renewable thermal energy at research stations will rely heavily on energy efficiency. Deep energy efficiency measures are easier to deploy at a research station than many other areas because all of the facilities are managed by a central organization. Electricity, or waste heat from electrical systems (for example, secondary loads from wind turbines) in combination with seasonal solar heating may provide the most direct path to a 100% renewable source for thermal energy. Biomass and biofuels are likely poor options for most remote research stations, although ground source heat pumps might be a viable alternative if permafrost and concerns about ecological sensitivity do not inhibit installation.

3.2.5.3 ELECTRICITY NEEDS

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Electricity will be necessary for equipment integral to conducting modern research (e.g. measurement equipment, computers, and communication systems). In addition, depending on the amenities provided to visiting scholars, electricity might need to be provided to residential buildings. Some tropical research stations provide tourism services to promote environmental conservation; however, outside of this there is unlikely to be any commercial or industrial electrical demands. The small scale of the electrical needs make research stations well suited to distributed PV applications, though the potential in stations near the poles may be limited during parts of the year.

PRIMARY RESOURCES AVAILABLE

Wind. In areas with long winters, the wind resource tends to be the best available resource. However, in extreme weather there may be substantial challenges in building appropriate foundations (see Scott Base and McMurdo station case study) and mitigating ice formation on wind turbine blades. Wind may also be appropriate in research stations in warmer climates. There may be special siting considerations for local bird species, particularly if the research station is near a protected area.\(^3^4\)

PV. Solar PV is a viable option worldwide, although research stations near the Arctic and Antarctic regions may have restricted solar resource in the winter; fortunately the majority of research activities occur in the summer months. In warm and tropical areas, the solar resource is likely adequate to make PV a strong option. Solar thermal generation typically requires a large installation to be cost-effective, which does not match the demand profile of most research stations.

Geothermal. Geothermal electricity is a highly site-specific resource, and is likely not feasible at most research stations due to the demand needs. A large installation would be necessary to be cost-effective. A potential exception would be research stations in highly volcanic regions, such as Iceland.

Hydropower. Like enhanced geothermal systems, hydropower is highly site-specific. A micro-hydro project, in particular, might be a good option where siting is suitable and where environmental protections allow micro-hydro systems to be installed. Small run-of-river systems are highly scalable and

\(^3^4\) For example, a wind turbine in Galapagos National Park was sited at an alternate location to protect the endangered Galapagos Petrel. See [http://www.eolcsa.com.ec/index.php?id=28](http://www.eolcsa.com.ec/index.php?id=28) for more information.
at the smallest level they have limited environmental impact, which can make them well suited to remote research stations.

ACHIEVING HIGH PENETRATION SCENARIOS
Depending on the resources available, high penetration renewable electricity may be considered at small research stations. Low penetration renewables have been piloted at a number of research stations, including several wind/diesel hybrid systems in Antarctica – for example Ross Island (see case study in Appendix A), or Germany’s Neumayer Station III\(^35\). These stations would be excellent candidates for high penetration renewables, although the importance of the research dictates that the transition be undertaken carefully. In warmer climates, PV is a scalable and cost-effective option for increasing the penetration of electricity from renewable sources.

3.2.5.4 TRANSPORTATION NEEDS

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS
The research stations are likely to be very remote, with transportation needs limited either for staff and supply delivery, or to undertake excursions into nearby research areas. Transportation is likely also to be included as part of a broader research agenda (e.g. transportation for field work). In many cases, it is limited to quads, snowmobiles, mopeds, and other small vehicles that can provide easier access in areas with limited infrastructure.

PRIMARY RESOURCES AVAILABLE
Biofuels. There is little opportunity for the cultivation of the current generation of plant-based biofuels (e.g. ethanol or biodiesel) in remote research stations, due to the likely unavailability of biofuel sources near remote research stations.

Electric vehicles. Electric vehicles powered by renewable electricity could potentially be deployed in remote research stations, particularly since the institutional structures likely lend themselves to centralized deployment of vehicles. A research facility will have likely only a few buildings, and these could be located near a transportation depot that uses electric vehicles. Colder climates may have challenges with shortened battery life due to cold weather, but selected technologies could be designed to withstand these colder temperatures. Also, smaller, lighter vehicles like quads may provide a useful application for emerging electric vehicle technologies.

ACHIEVING HIGH PENETRATION SCENARIOS
The vehicles at most research stations are part of the infrastructure provided by the managing organization or government. Research stations can leverage government programs and policies (e.g. fuel vehicle purchasing commitments) where applicable to facilitate a transition to an electrical vehicle fleet based on renewable energy, or a hydrogen-based fleet. High penetration in such areas will likely require either electric or some other battery-based storage option for ground transportation.

\(^{35}\) Neumayer Station III has a 30 kW wind turbine installed in a system with 600 kW of diesel genset capacity. See http://www.awi.de/en/infrastructure/stations/neumayer_station/ for more information.
3.2.5.5 OTHER CONSIDERATIONS

All renewable energy planning should be done in consultation with major research initiatives to ensure that the transition to increased renewables does not disrupt research planning or logistics. Renewable energy infrastructure construction will require the use of part of the residential facilities (potentially displacing researchers) and there may be special considerations for shipping logistics. This challenge is also an opportunity, since most planning can be done in consultation with a single, central organization that manages the facilities.

3.2.5.6 CASE STUDIES

A case study on the Ross Base and McMurdo Station on Ross Island in Antarctica was completed to illustrate the successful implementation of renewable energy in remote research stations.

The two stations are located at the southern tip of Hut Point Peninsula on Ross Island, Antarctica. Scoping studies for a wind and diesel hybrid project began in 2005, on-site testing in 2007, with construction commencing in November 2008, and commissioning in February 2010. Phase 1 was designed to be proof-of-concept, with later stages displacing up to 50% of the diesel production. The three wind turbines and flywheel storage system installed as part of Phase 1 provide 11% of the power needs of the island. Later phases may install more than twenty (20) wind turbines on the island.

3.2.6 ENERGY ACCESS IN DEVELOPING COUNTRIES36 (CATEGORY 6)

A primary distinction between developing areas and the other categories presented in this report is the goal of using RETs to enable or increase energy access, rather than reducing the impact of existing energy technologies. This has profound implications in terms of how energy efficiency is addressed, the choice of technology, as well as the expectation of service quality and reliability in these areas.

Remote areas in developing countries can be found through many regions worldwide,37 including Africa, East and South Asia, China, the Middle East, the Pacific, Latin America, and the Caribbean. More than 1.3 billion people live with limited energy resources, and no access to electricity (see Table 4). In addition to this, approximately 3 billion people cook their food and warm themselves with open fires using only cow dung, straw, wood, coal or charcoal (REN21, 2011). Some of these areas may have part-time electricity, with an estimated 10-15 GW of diesel gensets installed in remote areas of developing countries providing limited power access and significant electrification efforts have been on-going for many years (Aulich, 2008; Cust et al., 2007). For example, in 2000 alone, Brazil installed an estimated 400MW of diesel gensets in Amazonian regions (Goldemberg et al., 2000).

36 The term “developing” is used here for simplicity, despite its inaccurate implication that “developing” countries should be pursuing the development path of “developed nations”. Alternative metrics, such as the Happy Planet Index (http://www.happyplanetindex.org), which focuses on the ecological efficiency with which human well-being is provided, may be more appropriate.

37 It is challenging to characterise all remote areas in developing countries, for such some general specifics are highlighted with examples and this is by no means an exhaustive effort.
Table 4: Electricity access in 2009 - Regional aggregates (Source: IEA 2011)

<table>
<thead>
<tr>
<th>Region</th>
<th>Population without electricity million</th>
<th>Electrification rate%</th>
<th>Urban electrification rate%</th>
<th>Rural electrification rate%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>587</td>
<td>41.8</td>
<td>68.8</td>
<td>25.0</td>
</tr>
<tr>
<td>North Africa</td>
<td>2</td>
<td>99.0</td>
<td>99.6</td>
<td>98.4</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>585</td>
<td>30.5</td>
<td>59.9</td>
<td>14.2</td>
</tr>
<tr>
<td>Developing Asia</td>
<td>675</td>
<td>81.0</td>
<td>94.0</td>
<td>73.2</td>
</tr>
<tr>
<td>China &amp; East Asia</td>
<td>182</td>
<td>90.8</td>
<td>96.4</td>
<td>86.4</td>
</tr>
<tr>
<td>South Asia</td>
<td>493</td>
<td>68.5</td>
<td>89.5</td>
<td>59.9</td>
</tr>
<tr>
<td>Latin America</td>
<td>31</td>
<td>93.2</td>
<td>98.8</td>
<td>73.6</td>
</tr>
<tr>
<td>Middle East</td>
<td>21</td>
<td>89.0</td>
<td>98.5</td>
<td>71.8</td>
</tr>
<tr>
<td>Developing countries</td>
<td>1,314</td>
<td>74.7</td>
<td>90.6</td>
<td>63.2</td>
</tr>
<tr>
<td>World*</td>
<td>1,317</td>
<td>80.5</td>
<td>93.7</td>
<td>68.0</td>
</tr>
</tbody>
</table>

Remote areas in developing countries vary widely in access, needs, infrastructure, and resource availability. In addition, there is a challenge in determining suitable goals for these areas, since the existing expectations and use of energy will influence the most appropriate energy policy. Technological advances may help with leapfrogging traditional electrical generation from developed countries; however, the existing social and political constraints must be considered to ensure that RETs will be deployed in a system that will ultimately be maintained and be sustainable. Moreover, it is important to consider the overall development path as well as the particular needs of the communities in question.

### 3.2.6.1 ENVIRONMENTAL CONDITIONS

Environmental conditions in remote areas of developing countries vary widely. Communities in sub-Saharan Africa will have dry hot desert weather and cold dry winters, while Himalayan communities in India will suffer from cold and harsh winters, and communities in the Amazon have to deal with extensive rainy periods.

The environmental conditions for introducing RET from the other categories in this report (i.e., communities with long winters, temperate communities and large and small warm communities) will have many relevant considerations for developing areas. However, there are categories for remote areas for developing countries that do not fall neatly into the categories selected to be representative of IEA-RETD countries.

As with the categories above, the following sections are divided into three broad categories capturing the basic areas of energy needs in remote areas:
Thermal energy needs
Electricity needs
Transportation needs

Each of these subsections is considered in terms of the energy demand and infrastructure considerations, the primary resources available in this remote area category, as well as the unique considerations relevant to achieving high levels of renewable energy penetration in that area.

3.2.6.2 THERMAL ENERGY NEEDS

ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS

Space heating demands will be limited to remote areas in high altitudes or located in northern regions (e.g. Indian Himalayas, Andean communities, and Subarctic Siberia). Remote communities have survived for thousands of years using solid fuels for heating (e.g. wood, charcoal, cow dung, etc.), however access to fuels can be an issue and there is a number of special health risks related to poor heating equipment (e.g. exposure to smoke, fires).

Although space heating may be limited to cold and temperature climates, remote communities will have high thermal energy demands for cooking. Most remote communities rely on solid fuels for cooking, although some more developed areas may use LPG and limited electric stoves. In colder climates, cooking indoors may be of dual use for preparing food and for residential heating. In both instances, more efficient cook stoves with appropriate ventilation can reduce demand for heating fuels and improve indoor air quality. Hot water is also an increasing demand, although primarily in larger remote areas (e.g. in Small Island Development States (SIDS) like the Maldives, San Andrés, Colombia).

Cooling demands may be desired in warm and tropical areas (e.g. Kiribati, Tonga, Andaman Islands, St. Lucia), which can be most efficiently met with fans rather than A/C. Many tropical developing areas do not use artificial cooling, but it is unclear whether this is driven by culture or energy poverty. Regardless, larger tropical islands have increased significantly the use of A/C units, which creates a weekday mid-day peak when commercial and public buildings are open.

Agriculture and industry may also have thermal demands, but this will vary widely and will need to be analysed on a geographic region-by-region basis.

PRIMARY RESOURCES AVAILABLE

Biomass. The availability of biomass resources depends on the location of the remote community. In warm and tropical areas there will be considerable amount of agricultural residues, livestock waste, and wood, which will be less in colder mountainous regions and deserts. Biomass represents the highest energy source used in remote areas of developing countries to meet their energy needs (Parikka, 2004). Many remote areas already use biomass for cooking and space heating, and care should be taken to ensure that the resource is sustainable under existing usage. More efficient cooking stoves and heating methods may provide an excellent option for mitigating these challenges. Moreover, in areas such as
sub-Saharan Africa, biomass may not be considered a “renewable” resource at all, posing further challenges to implementing a sustainable energy strategy in such regions.

**Solar thermal.** Solar resource availability will predominate in warm areas like sub-Saharan Africa, Pacific Islands, India and some areas in East Asia (see Figure 4). Highly forested areas like the Amazons will have a more limited amount of solar resource that will decrease during the rainy season. Northern remote communities will have low solar potential, particularly in the winter months in polar communities.

Solar is commonly used for crop drying and solar cooking. In addition, many small Caribbean and Pacific Islands are making efforts to introduce solar water heaters.

**Geothermal heat.** Geothermal heat will be site specific. There are limited cases where geothermal heat pumps (GHPs) have been used in developing remote areas. Typically, the costs were deemed too high and other alternatives can be selected (e.g. heating stoves and solar thermal applications).

**ACHIEVING HIGH PENETRATION SCENARIOS**

Many heating and cooking needs may already be met with renewables resources, in particular biomass. However, traditional methods of burning biomass may be improved with newer technology. Improvements may include increasing stove burning efficiency to prevent the negative effects of deforestation and improving ventilations to reduce health risks related to open smoke cooking and/or heating stoves. A series of different technologies are being implemented worldwide. For example, an estimate of 830,000 people have benefited from improved cook stoves as of 2009 (Legros et al., 2009). Energy source substitution may also provide benefits. Biogas production with biomass wastes (e.g. livestock manure) is being used in China and many other countries (e.g. India, Nepal and Bolivia) for space heating or cooking stoves, with an added benefit of improved sanitation (Buysman, 2009; Zhou et al., 2004).

Even if heating needs are mainly met with a sustainable biomass resource, challenges reside in making a transition to more sustainable uses. In addition, a combination of improved design, technological leapfrogs (cow dung to biogas), practical solutions, new technologies and improved efficiency will play major roles in achieving high penetration of RES for thermal energy needs.

Space heating and cooling needs can be reduced with improved insulation and efficiency measures in households, like solar passive houses (Agniel et al., 2009; Chandel, 2009). Cooling needs should be designed to meet the demand of the local population, who may not need, or want, artificial space cooling. In many areas, proper ventilation and improved traditional construction can be used to reduce and prevent the need for artificial space cooling. If there is demand for artificial cooling demand, fans can often provide adequate cooling; A/C units should be discouraged.

**3.2.6.3 ELECTRICITY NEEDS**

**ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS**

Electricity demand in remote areas of developing countries will vary considerably between populations and regions. The most common needs are lighting, radio, mobile phones, and some small productive
uses (e.g. wood shops, chicken incubators, shops). In addition, some communities (mainly those that already have access to electricity through diesel gensets or other) may require electricity for refrigerators, washing machines, and other appliances. In many communities, electricity is available in public spaces but not in individual residences. Public areas need electricity for public lighting, communal centres, health clinics, water pumping, schools, and IT centres. Electricity may also be needed to develop commercial activities and industry. Load profiles that represent common consumption patterns in remote areas can be defined (Vallvé et al., 2010).

If there is no electricity access, remote communities will most likely rely on kerosene lamps, batteries and candles for lighting, and other alternatives to supply their energy needs. Although electricity can meet a wide variety of needs, UNIDO recommends careful consideration of electrification and further proposes that electricity may not be the most appropriate form of energy in many developing areas. UNIDO recommends first considering technological interventions including more efficient cook stoves, mechanical water pumps, or other practical solutions. In many instances, these non-electrical interventions are less expensive and more appropriate than electricity (UNIDO et al., 2003). Regardless, a careful demand study of electricity and other energy needs must form part of any rural electrification project, and the latter must be informed by an understanding that electrification of developing areas may lead to rapid demand growth (see Akkan, Morocco and Floreana, Galapagos Islands, Ecuador case studies). One major reason for this is that access to appliances and other electronic devices is more widespread, lower cost, and occurs in an uncoordinated fashion driven by individual purchases – this contrasts with the addition of electricity infrastructure, which is scarce, high cost, and typically requires careful planning.

**PRIMARY RESOURCES AVAILABLE**

**Wind.** Wind resources are site-specific, although small wind applications have been increasing in rural areas of developing countries through small-scale applications of 5 – 100kW wind turbines in village hybrid systems (REN21, 2011). For example, wind/diesel hybrids have been successfully deployed in Chiloe Archipelago in Chile. Larger remote areas have been also integrating larger scale wind turbines (>100kW) into their grid systems. For example, Rodrigues Island in Mauritius integrated 180kW of wind turbines into their 6MW grid (SWIIS, n.d.). Most applications currently remain limited to pilot projects.

**Solar PV.** PV has been one of the most widely used RETs in rural areas of developing countries. Annual solar irradiation is considerable in most areas and the modularity of PV eases its installation in developing remote regions. Solar home systems (SHSs) have been introduced in millions of communities, providing limited access to electricity, radio, and other small appliances. PV for water pumping has also been widely applied; by the year 2000 more than 20,000 PV-powered pumping systems were installed worldwide (Lynn, 2010). PV/hybrid systems are also becoming an electrification alternative that allows more power access (Alliance for Rural Electrification, 2010).

---

**Geothermal.** Although developing countries are pursuing geothermal electricity, geothermal is not typically used as an access strategy, and small communities with limited electricity demand will have little applicability for the development of geothermal projects.

**Hydropower.** Hydropower, if available locally, has great potential and is one of the most cost-effective options for electrical generation. Small-hydro projects are increasingly common and are being implemented in many small remote areas worldwide (e.g. Woodruff, 2007). In larger regions, large hydro resources may already be developed, although there may be opportunity for smaller, run-of-river development and efficiency upgrades.

**ACHIEVING HIGH PENETRATION SCENARIOS**

SHSs are increasingly being deployed in developing areas, typically in a non-systematic way from a variety of public and private development organizations. In Africa more than half a million SHSs were in use in 2007, 400,000 systems in north-western China, and approximately 800,000 in India (REN21, 2011). Although progress towards electrification is being made, there is still a need for sustainable models to ensure widespread deployment and to ensure that adequate maintenance services are available locally.

Many rural areas are not aware of the benefits of electrification, and there is strong anecdotal evidence that local demand and strong community involvement are key drivers for successful development projects. The successful Barefoot College in India uses local capacity, education and the possibility of employment to increase demand for electricity in rural areas. There is a technical potential for smaller communities to achieve high penetration RE systems, but they are often constrained by purchasing capacity, technical skills, and more pressing subsistence priorities.

**3.2.6.4 TRANSPORTATION NEEDS**

**ENERGY DEMAND AND INFRASTRUCTURE CONSIDERATIONS**

Transport demand in developing remote areas varies significantly, although it is mainly met by foot traffic in combination with intermediate means of transport (IMT) such as buses and bicycles (Dennis, 2001). The primary transportation needs are for water, food, and fuel for cooking, although many also serve economic ends (e.g. selling produce, commuting to work, trading), education, health care, and leisure. In many instances, the limited transport options, poor road infrastructure, and long distances combine to create long travelling times for residents in remote areas. IMT options such as bicycles can address both of these concerns while not increasing the demand for liquid fuels.

Many developing areas will use liquid fuels for limited vehicles and boats, often in the form of a public transportation service or the vehicles of wealthier individuals or expats. The limited amount of powered-transport in the communities themselves will suffer the same fuel access challenges, with common disruptions in delivery and high fuel costs. More densely populated remote areas will tend to have similar transport demands and challenges as defined in the other categories.

---

39 More information per country can be found at: [http://www.small-hydro.com/index.cfm?fuseaction=welcome.home](http://www.small-hydro.com/index.cfm?fuseaction=welcome.home)

40 For more information see: [http://www.barefootcollege.org/](http://www.barefootcollege.org/)
PRIMARY RESOURCES AVAILABLE

Biofuels. With regard to remote areas in developing countries, there may be limited access to adequate infrastructure or technical capacity necessary for harvesting and processing biofuels.

Electric vehicles. Smaller remote areas will have limited need for vehicle use and will likely benefit more from increasing access to other energy services rather than from electric vehicles. IMTs such as bicycles may prove a more appropriate, intermediate technology solution for many remote developing country regions.

ACHIEVING HIGH PENETRATION SCENARIOS

A high penetration of renewables in the transportation sector is considered challenging in the near term in remote areas of developing countries.

3.2.6.6 CASE STUDIES

AKKAN, MOROCCO

A case study on the PV Hybrid Microgrid project in Akkan, Morocco was completed to illustrate the successful implementation of renewable energy in the remote areas of developing countries.

Akkan is an isolated hamlet (douar) in the province of Chefchaouen with 35 households, a school and a mosque. Prior to the completion of the PV Hybrid Microgrid, access to energy services was limited to candles, kerosene, wood and batteries. This project was implemented as a pilot demonstration in 2005 by local consultants in the community. By 2006 the construction began on a project to provide electricity to 30 households, a school, the mosque, a communal house and public lighting. Users report high satisfaction with the system, but have begun to request greater electricity availability.

3.2.7 LESSONS LEARNED FROM CASE STUDIES OF REMOTE AREAS

Specific lessons learned about renewable energy in remote areas were developed for each of the case studies described in Section 3.2 above and are included in Appendix A. This section summarizes the lessons learned that are generally applicable and groups them according to whether they relate to technical, socio-economic, institutional, financial or environmental considerations.

The lessons learned are meant to provide insight into some of the basic insights that may help in accelerating the transition to more sustainable energy systems for remote communities. These include ideas like creating energy plans, engaging the local community, emphasizing energy efficiency, and a host of other potential areas for improvement. The lessons learned are divided into the following categories:

1. Technical lessons learned
2. Socio-economic lessons learned
3. Institutional lessons learned
4. Financial lessons learned
5. Environmental lessons learned
A high-level summary of the applicability of various considerations based on the case studies and lessons learned is summarized below in Table 2 below provides a high-level summary of the specific considerations as they relate to each category. The results presented are a general summary to provide a starting point for engaging with each of the remote areas; individual remote locations within a category may vary. The table covers a range of considerations. The energy needs specifies how much demand there will be for each energy type, the resource availability summarizes the expected renewable resource availability, the access challenge summarizes the expected difficulty of transportation access to the remote area, the climate specifies the type of climate that can be expected throughout the year, and the demand type breaks down the typical split along expected energy consumer types. Each of the areas may also be expected to differ in the availability of governance infrastructure and the expected levels of energy poverty. The table also provides a summary of the short- to medium-term renewable penetration that can be expected, although in the longer term it is expected that 100% renewable will be possible.

Table 2.
Table 5: Summary of the case studies that showcase particular lessons learned

<table>
<thead>
<tr>
<th>Theme</th>
<th>Lesson learned</th>
<th>Kodiak Island</th>
<th>Long-winters</th>
<th>Paro Island</th>
<th>Tarapaca</th>
<th>Eigg Island</th>
<th>Rokana</th>
<th>Coral Bay</th>
<th>Bonaire</th>
<th>El Hierro</th>
<th>Miyako</th>
<th>Reunion</th>
<th>Ross Island</th>
<th>Redland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Assess demand</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Energy efficiency first</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Identify renewable energy resources</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Plan future demand</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Infrastructure integration plan</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>O&amp;M strategy and budget</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Transition plan</td>
<td>High penetrations are possible</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Large, low-penetration RETs</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Small, high-penetration RETs</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Testing technologies</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Technical integration</td>
<td>Complementary generation to meet demand</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Storage</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Improved diesel controls</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Improved demand response</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Remote monitoring</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Local benefits</td>
<td>Economic vitality</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Local quality of life</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Reduce necessary subsidies</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Community involvement</td>
<td>Use and develop local expertise</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Community participation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Begin a local sustainability portfolio</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Local private sector participation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Institutional capability</td>
<td>Adapt national policies</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>New institutions and regulations</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Integrated utility system</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Alternate tariff structures</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Financial</td>
<td>Public support</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Contextualize costs for remote areas</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>R&amp;D can support remote projects</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Public funds to leverage private funds</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Impact of fuel subsidies</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Development risks</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Environmental impacts</td>
<td>Direct environmental protection</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Consider local weather</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

41 The lack of a check mark does not indicate that the lessons learned do not apply to the case study in question. Instead, check marks indicate the lessons learned that were highlighted in each case study.
3.2.7.1 TECHNICAL LESSONS LEARNED

RENEWABLE ENERGY SYSTEMS IN REMOTE AREAS REQUIRE CAREFUL PLANNING

The development and management of energy systems in remote areas requires a significant amount of planning – even if those grids rely exclusively on diesel generators. Remote areas cannot count on neighboring communities (or countries) to help balance electricity supply and demand, for example. The planning of remote energy systems can require a series of closely inter-related steps, summarized below.

- **Assess current energy usage and demand.** It is important to undertake a detailed energy demand assessment (a recurring theme in all case studies). The assessed demand will be used to determine the size of the renewable energy system (or fuel demand) and identify appropriate technological and/or policy strategies to manage or reduce demand. In Coral Bay, for example, the town set a limit on the number of overnight visitors allowed each day to ensure that the local infrastructure can adequately and cost-effectively meet all energy demands without sacrificing the long-term vibrancy of their tourism industry (see Coral Bay case study).

- **Identify opportunities for energy efficiency.** Maximizing efficiency measures and encouraging efficient energy behavior before assessing generation technologies can significantly reduce the installed costs of renewable energy systems (see Bonaire and the Faroe Islands case studies). In Floreana, the local utility provided incentives for high-efficiency refrigerators to reduce costs overall (see Floreana case study). Other examples include the possibility for increased use of smart meters, which can help enhance conservation efforts through greater awareness, and the use of demand response. It is important to note, however, that access to more efficient appliances might be limited in remote areas, hence identifying market availability of products is important or ensuring the local population has access to these products, or to create the channels required to make them more widely available.

- **Identify renewable energy resources.** The full range of potential renewable energy resources should be assessed in order to determine how best to optimize the costs of different systems and the different values that they provide to the energy system.

- **Plan for future energy needs.** The system should take future demand growth into account (or decline – see Ramea). If the system will dramatically improve the availability of energy, for example, substantial load growth can occur and should be considered in the design (see Floreana and Akkan case studies). Projected load growth can be managed, for example, by providing firm caps on user demand to make future demand growth more predictable (see Eigg and Akkan case studies). These caps can be enforced by providing real-time feedback such as alerts to energy users on their energy consumption (see Eigg case study).

- **Develop an infrastructure integration plan.** Based on assessments of available resources, and energy demands, the energy systems can be optimized to achieve the maximum renewable energy

42 The IEA Demand Side Management group has developed a number of tools for implementing energy efficiency and demand management in various markets., http://www.ieadsm.org
penetration at the most appropriate price levels, taking into account technical limitations. For electricity systems, optimization tools such as the HOMER software system or RETScreen can be used to analyse scenarios involving different penetrations of different resources.

- **Create an operations and maintenance strategy. RETs can reduce the logistical burden of system operation, but proper maintenance is even more critical.** Operations and maintenance plans in remote areas must be more carefully considered given the challenges with sources technical expertise and spare parts. The case studies presented a number of options for ensuring that the hybrid and renewable technologies received proper attention. Several of the remote areas made provisions to either stockpile spare parts or create contingency funds to support spare parts delivery. In Akkan, a special O&M budget was created to ensure that the RET investment was protected, and involving local residents in the maintenance plans further supported this objective (see Akkan case study). In isolated areas, the reduced logistical burden can be used to ensure operation even if transport routes become blocked seasonally (see Ross Island case study).

This type of planning is similar to the steps required in non-remote areas. However, planning in remote areas must often be more specific, intensive and front-loaded because the small-scale of the systems increases the need to carefully match resources with demand, and the need to utilize resources such as storage, demand response, controls, smart meters, etc. in an integrated and sophisticated way as penetration levels increase. An example of such planning is the development of training, staffing and staff succession plans in the Northwest Territories in Canada. In this case, the territorial government assists in developing ‘Integrated Community Sustainability Plans’, which create a framework for planning, technical needs, and succession in remote communities. Such plans could be used on a wider scale in other remote areas where the appropriate governance structures are in place.

**A TRANSITION PLAN CAN FACILITATE SMOOTH RET INTEGRATION**

One of the key lessons learned for increasing the use of renewable energy in remote areas is to create a plan that drives an appropriately staged increase in the penetration of RETs. There are a number of reasons that a smooth transition to higher renewable penetrations is important, but building local knowledge and skills is the primary success factor. The following options have been used successfully to transition to a system with more RETs:

**High penetrations of renewable electricity are possible.** Several of the case studies have demonstrated that high penetrations of renewable electricity are possible if appropriate supply side, demand side, storage and control systems can be integrated. Eigg Island, El Hierro, Bonaire, and Akkan are all at 60%-80%+ renewable electricity and some like Bonaire and Reunion have plans for 100%. It is interesting that the remote areas studies have focused primarily on renewable electricity. Although there were instances in which renewable heating technologies or renewable transportation fuels (e.g. E3 blend in Miyakojima Island) were being introduced, none of the case study areas were pursuing high penetrations of renewable thermal or renewable transportation. An exception to this was Nólsoy in the Faroe Islands, in which wind turbines are dedicated to generating electric heat for a third of the households and in which planned geothermal heat pumps will cover a significant proportion of the space heat load. Future
research could focus on case studies of high penetrations of renewable heating and transportation technologies in remote areas.

**Low-penetration systems can be installed before attempting higher penetrations.** Low renewable penetrations in large systems are easier to manage than a high-penetration system (see Bonaire, the Faroe Islands, El Hierro, and Kodiak case studies). Low penetration installations allow utilities or developers to test functionality, responsiveness and success of RETs that will allow them to gain experience before attempting higher penetrations. The lower risk of low penetration systems can be helpful in getting the buy-in of the local utility and the general public, who may be wary of rapid change (especially change that is being promoted by outsiders unfamiliar with their situation).

**Small-scale, high-penetration system can be pilots for larger-scale high-penetration systems.** Deploying a small system with high penetration (see Floreana case study) can provide valuable experience. Electricity systems with average demand less than approximately 150 kW can transition more quickly to high penetration due to the ready availability of power management hardware at this scale (Entura, 2010). Such pilots can then serve as models for neighboring areas. After the installation of the Floreana mini-grid, for example, San Cristobal Island also in the Galapagos began developing a larger PV installation. This strategy requires that the smaller-scale pilot project be very well supported to make sure that problems are fixed quickly and that the results are well publicized.

**Remote areas, if properly supported, can be testing grounds for almost mature technologies or applications.** Projects in remote areas provide experience that is becoming increasingly valuable to non-remote energy systems. However, the remote location must have access to robust monitoring and strong institutional support to prevent poor outcomes and to capture lessons learned. When deciding if technologies are appropriate for remote areas, it is important to balance the potential diesel fuel savings with the additional challenges for supporting the technology. For example, the KREC Building in the Faroe Islands piloted solar thermal in the region (see Faroes case study) and the island of Unst in the Scottish Isles is testing wind-powered hydrogen storage for transportation (SMALLEST, 2008). These pilot projects provide experience that can lead to broader uptake as the technologies become more cost-effective. Miyako Island piloted a PV/diesel hybrid system in the late 1990s, which has provided critical experience for the recent and larger PV hybrid smart grid research project (see Miyako case study).

**AN INTEGRATED SYSTEM CAN SUPPORT RELIABILITY**
An integrated, hybrid approach to renewable technologies can leverage the strength of different technologies and improve performance over stand-alone or single-technology systems. The need for integration means that a proper balance of system equipment is essential to the successful integration of RETs.

**Generation technologies can complement each other and can be matched in different ways to energy demand.** In the systems studied, each of the energy technologies provided different value to the system. PV or wind resources typically provide bulk energy, whereas diesel generators provide the reliability that end-users demand (this is a recurrent theme in most case studies). Hydro, if available, can also help to provide the reliability (see Kodiak, Reunion and El Hierro case studies). Renewable technologies can also
be complementary – for example solar and wind together may provide greater value than either alone – the wind often blows when the sun doesn’t shine (see Eigg case study). A technology may also be more appropriate based on the system demand; for example, in areas with long winters the wind often blows hardest during the winter when energy demands are highest. Electrical systems can often provide additional value to non-electrical energy demands; excess energy from renewable sources can often be used to meet thermal loads (see Faroe case study). Each of these examples is highly site specific, but demonstrate that further investigation is appropriate for most remote areas.

Remote areas are at the forefront of innovative use of storage. Storage is used to maximize grid performance in the case studies by providing different services, including shifting electricity production to times of demand, balancing intermittent output, and improving grid stability and the technical performance and efficiency of the diesel generators (see Faroe Islands, Ramea, Miyakojima, Reunion and El Hierro case studies). Batteries are the most common technology in the case studies, although alternative storage technologies such as flywheels, hydrogen, advanced batteries and pumped hydro are all in use in the remote areas studied.

Reliability can be supported through improved controls for the diesel generators. Specialized diesel equipment also can be used to improve the maximize the benefit from RETs and improve the diesel genset performance in hybrid systems – for example, gensets that can operate at low loads (see Coral Bay case study), and automatic starters for gensets (see Floreana case study).

Reliability also can be supported with demand response and other demand resources. Consumer or other loads can also be strategically turned on to absorb excess renewable electricity or turned off to shed demand when renewable output is low (see El Hierro and Reunion case studies). Such loads should be identified during the planning process and integrated into system management plans.

Remote monitoring and system control can provide critical information to manage the system. There is a limited supply of qualified technicians in remote areas. While it is important to develop local capacity, with modern monitoring equipment remote areas can more readily leverage the expertise of non-local experts. Remote system performance monitoring will help technicians monitor each piece of equipment and ensure proper operation of the overall system (Bopp and Graillot, 2007) (see also Floreana and Reunion case studies). Smart meters at user sites can also provide information and control options that help to integrate system supply and demand (see Akkan, Reunion and El Hierro case studies). Remote monitoring can also be used to implement tariff structures that encourage or limit demand at the right times.

3.2.7.2 SOCIO-ECONOMIC LESSONS LEARNED

RENEWABLE ENERGY CREATES LOCAL BENEFITS FOR REMOTE AREAS

Renewable energy systems can support a range of economic activity. In many cases, the projects directly created local jobs (see Eigg and Reunion case studies). However in some instances, the installations themselves can indirectly bolster other local industries; in Miyako Island, the PV installation traces along part of the route of a major annual triathlon, which as a result has been used to promote tourism flows (see Miyakojima case study). In other cases, the improved energy services will enable new
local industries. For example, in Floreana the upgraded electrical system enabled local residents to create high-efficiency egg incubators for their chicken industry (see Floreana case study).

**RETs can create opportunities to improve the quality of life.** In most of the cases, the introduction of renewables to remote grids reduced price volatility and/or the cost of power, benefits which are passed along to power users (see Kodiak and Faroe case studies). Renewables can also to improve local satisfaction with the provision of basic energy needs (see Akkan case study).

**Renewable energy can reduce the amount of subsidies required.** In several of the case studies, the projects directly lowered the operational deficit covered by government. This benefit was particularly pronounced in El Hierro, where the project is projected to reduce the annual subsidies from the government by €3.55 million each year. Benefits have also materialized in areas like Miyakojima, and Ramea.

**COMMUNITY INVOLVEMENT IS IMPORTANT TO ENERGY DEVELOPMENT IN REMOTE AREAS**

Locally inclusive renewable energy strategies can be fundamental to building strong and resilient energy infrastructure in remote areas. Strategies that incorporate local stakeholder involvement in all project stages (from planning through construction to ongoing operation) can maximize community benefit (see Text Box 2 on Samsø Island).

**Local expertise can be developed and utilized to support system operation.** There are a number of approaches to building local capacity that have been successfully used in the case studies. In Kodiak, the equipment manufacturer provided maintenance as well as training during the first two years of operation, which enabled local staff to better manage their renewable assets (see Kodiak case study). Relying on local or regional expertise and labor can lead to longer-term proper maintenance and technician availability (see Akkan and Eigg case studies). Capacity building can enable local residents to maintain the systems, which can reduce overall system costs. Local education programs can be used to build local capacity to maintain the system (see Bonaire case study). In some instances, partnering a project with a local academic institution can help to improve of local capacity building (see El Hierro and Ramea case study). This can also build capacity among the institutions that provide power. The Ross Island wind turbine was installed with the consultation of a 25-year veteran of the region (see Ross Island case study). The availability of similar technical assistance for other types of remote areas could support renewable energy development in areas without existing local capacity.

**The community should be engaged in the project.** The participation of community members in energy projects is particularly important in remote communities given their small size. For example, in the Isle of Eigg, the community was not only a strong driver for the installation of renewables, but helped to reduce system costs by providing in-kind support and local expertise to improve the installation (see Eigg case study). By contrast, in El Hierro the community did not initiate the project, but were successfully consulted early in the project planning process, which helped minimize community resistance to the project (see El Hierro case study). In Akkan, the community has maintained the system for 5 years without major issues, even though the national government and utility have not been heavily involved in the process. In Samsø Island, the wind projects issues shares in wind power projects to enable local
residents to invest directly, enabling citizens to benefit financially as well as environmentally from the increase in renewable energy. Finding innovative vehicles to allow local sources of financing to participate can play a vital role in increasing community acceptance, and engagement.

**RETs can be part of a broader sustainability portfolio and lead to “greener” communities.** The installation of RETs can provide a turning point to create more environmental awareness in remote communities. For example, in the Isle of Eigg, the renewable energy project improved local awareness of environmental issues, and residents are now more likely to insulate their households, participate in community gardens, and use their vehicles less (see Isle of Eigg case study).

**The local private sector can be engaged to support energy system development.** Although energy systems in remote areas are often characterized by heavy public sector support, local private sector partners played important roles in some of the cases studied. In some cases, the local residents, businesses, and other community organizations invested directly in the project (see Eigg, Faroe, and Akkan case studies).

### 3.2.7.3 INSTITUTIONAL LESSONS LEARNED

The institutional framework varies widely between remote areas and differs from that in mainland areas – there are differences in institutions and stakeholders, as well as their relative roles. The institutional framework will depend on issues such as government structure, the relationship of the remote area government to the national government (if applicable), utility structure and regulation, and electricity market structure conditions. Depending on how these conditions align, the public sector, private sector, or community will play different roles in remote area energy management. As can be seen in Table 6, the system ownership structures in each of the case studies varies widely with a full spectrum of potential models represented. A broader consideration of the interaction of different institutions in remote areas is recommended for further research. This section summarizes some of the institutional lessons drawn specifically from the case studies and Section 4 discusses potential policy recommendations.

<table>
<thead>
<tr>
<th>Project</th>
<th>Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kodiak</td>
<td>odiac Electric Association (cooperative utility)</td>
</tr>
<tr>
<td>3 x 1.5 MW wind</td>
<td></td>
</tr>
<tr>
<td>Ramea</td>
<td></td>
</tr>
<tr>
<td>Phase 1 – 6 x 65 kW wind</td>
<td>Phase 1: Frontier Power Systems (developer)</td>
</tr>
<tr>
<td>Phase 2 – 3 x 100 kW wind and 250 kW hydrogen system</td>
<td>Phase 2: Nalcor (state-owned utility)</td>
</tr>
<tr>
<td>Faroe Islands</td>
<td></td>
</tr>
<tr>
<td>2.13 MW wind</td>
<td>SEV (municipal utility)</td>
</tr>
<tr>
<td>1.98 kW wind</td>
<td>S/F Røkt (developer)</td>
</tr>
<tr>
<td>220 kW wind for electrical heat</td>
<td>NólsoyarOrkufelag (community company)</td>
</tr>
<tr>
<td>Solar thermal 200m², 10kW wind and hydrogen storage system</td>
<td>Community non-profit</td>
</tr>
<tr>
<td>Project</td>
<td>Ownership</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>Isle of Eigg</td>
<td></td>
</tr>
<tr>
<td>100 kW Mini-grid</td>
<td>Eigg Electric Ltd (community-owned utility)</td>
</tr>
<tr>
<td>Floreana</td>
<td></td>
</tr>
<tr>
<td>Phase 1: PV / diesel / battery hybrid</td>
<td>Junta Parroquial de Floreana (local authority)</td>
</tr>
<tr>
<td>Phase 2: 2 x 68 kW diesel gensets (fueled by jatropha)</td>
<td>Elecgalapagos S.A. (utility)</td>
</tr>
<tr>
<td>Coral Bay</td>
<td></td>
</tr>
<tr>
<td>3 MW wind/diesel/storage mini-grid</td>
<td>Verve Energy (state-owned generation company)</td>
</tr>
<tr>
<td></td>
<td>Horizon Power (state-owned distribution company)</td>
</tr>
<tr>
<td>Bonaire</td>
<td></td>
</tr>
<tr>
<td>wind/diesel/storage hybrid</td>
<td>EcoPower Bonaire BV (private IPP)</td>
</tr>
<tr>
<td>El Hierro</td>
<td>Gorona del Viento (public/private partnership IPP)</td>
</tr>
<tr>
<td>Miyakojima</td>
<td></td>
</tr>
<tr>
<td>4 MW PV / battery smart grid</td>
<td>Okinawa Electricity Power Company (utility)</td>
</tr>
<tr>
<td>Reunion Island</td>
<td>Varied ownership, some public, some hybrid, some private.</td>
</tr>
<tr>
<td>Scott Base and McMurdo Station</td>
<td></td>
</tr>
<tr>
<td>3 x 330 kW wind turbines / flywheel</td>
<td>Antarctica New Zealand (a state-owned Crown corporation)</td>
</tr>
<tr>
<td>Akkan</td>
<td></td>
</tr>
<tr>
<td>PV / diesel / storage microgrid</td>
<td>Joint ownership by municipality and community organization</td>
</tr>
</tbody>
</table>

**National policies may need to be adapted to promote renewables in remote areas.** In some cases, national energy policies may need to be adapted to accomplish their intended outcome when applied to remote areas. For example, the United Kingdom created a feed-in-tariff (FIT) specific to remote areas that helped the Isle of Eigg increase the amount of renewable energy on their grid (see Isle of Eigg case study). Similar success with FITs has occurred in Reunion, where island residents can receive a slightly higher FIT price than mainland projects on technologies such as solar PV. Conversely, in Floreana the requirements to qualify for the national FIT policies were overly burdensome and prevented their remote grid from capturing the intended benefits (see Floreana case study).

**Renewable energy in remote areas may require new institutions and regulatory environments.** Community-led energy development can also provide an effective alternative for increasing renewable energy (see Akkan case study), even when the local government or public utility is unable (or unwilling) to provide support. In Eigg, for example, the community had to create an independent utility since the
grid was not going to be extended. In the Faroe Islands, a community-owned company was created to own and operate a wind turbine that supplies electrical heat to the community since the utility does not permit turbines to feed power into its grid. The existing regulatory framework may pose barriers that need to be addressed in order for new models to be explored. The process of creating new institutions can also be burdensome for communities and they must either find financing themselves for design and implementation, or seek alternative financing from private and development funds.

Remote areas may benefit from an integrated utility system, particularly when installing hybrid power systems. Hybrid power systems require substantial technical coordination in order to integrate intermittent renewables. Technical requirements, such as the optimal dispatch of storage, may be more easily met when a single institution manages the full system (see Kodiak, Miyakojima and Eigg case studies). This is particularly true for high penetration and smaller-scale systems. A clear definition of responsibility is critical to prevent poor system operation, particularly when equipment falls under the jurisdiction of several entities. For example, in Floreana responsibility for battery maintenance was unclear, which led to early battery failure (see Floreana case study). Depending on the size of the remote area, market structure, or other variables, however, it may be practical to enable independent energy generators to develop low penetration projects (see Bonaire and Faroe Islands).

Alternate tariff structures can be developed that are specific to a remote area. An alternate tariff structure specifically designed for a remote area may help to manage demand and improve the integration of RETs. There are numerous possible tariffs. For example, a monthly flat rate tariffs that provides each connection a daily energy allowance (see Floreana case study) may be more appropriate than a tariff with no usage limits. Consumption above the standard allowance can be charged a rate high enough for full cost recovery of the incremental usage. Similarly, tariff structures that react to energy production (i.e. low rates to encourage consumption when wind is high and vice versa) can be implemented to support grid integration. Remote monitoring tools and technologies may facilitate the implementation of alternative tariff structures while also reducing the administrative burden of reading meters and enabling better system control.

3.2.7.4 FINANCIAL LESSONS LEARNED

The financing strategies for each of the case studies are summarized in Table 7 below. As can be seen in the table, a broad range of different financing strategies were applied in each of the different case studies.
<table>
<thead>
<tr>
<th>Project</th>
<th>Financing Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kodiak</td>
<td>82% utility financed 18% grant financed</td>
</tr>
<tr>
<td>Ramea Phase 1 – 6 x 65 kW wind</td>
<td>Phase 1: 49% private 51% grants and public loans</td>
</tr>
<tr>
<td></td>
<td>Phase 2: 25% utility financed 75% grants</td>
</tr>
<tr>
<td>Faroe Islands 2.13 MW wind</td>
<td>Utility financed</td>
</tr>
<tr>
<td></td>
<td>Privately financed</td>
</tr>
<tr>
<td></td>
<td>86% grant, 14% community equity</td>
</tr>
<tr>
<td></td>
<td>100% grant to date</td>
</tr>
<tr>
<td>Isle of Eigg 100 kW Mini-grid</td>
<td>Funding from seven different public and private sources, including 6% from island residents</td>
</tr>
<tr>
<td>Floreana Phase 1: PV / diesel / battery hybrid</td>
<td>Phase 1: international donors, national / local government and users</td>
</tr>
<tr>
<td></td>
<td>Phase 2: National government and international donors</td>
</tr>
<tr>
<td>Coral Bay 3 MW wind/diesel/storage mini-grid</td>
<td>46% utility financed 54% grant financed</td>
</tr>
<tr>
<td>Bonaire wind/diesel/storage hybrid</td>
<td>100% private project finance (80/20 debt:equity)</td>
</tr>
<tr>
<td>El Hierro</td>
<td>10% private finance 35% public finance 55% grant</td>
</tr>
<tr>
<td>Miyakojima 4 MW PV / battery smart grid</td>
<td>Federal research and development funds</td>
</tr>
<tr>
<td>Reunion Island Large and small solar PV, solar thermal, wind, ocean, hydro, storage, algae, EVs</td>
<td>Varied financing structures, including public, hybrid, and private</td>
</tr>
<tr>
<td>Project</td>
<td>Financing Structure</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Scott Base and McMurdo Station</td>
<td>100% grant funded</td>
</tr>
<tr>
<td>3 x 330 kW wind turbines / flywheel</td>
<td></td>
</tr>
<tr>
<td>Akkan</td>
<td>80% grant</td>
</tr>
<tr>
<td>PV / diesel / storage microgrid</td>
<td>20% community equity</td>
</tr>
</tbody>
</table>

Many of the remote areas rely heavily on public resources because of the need to install generation and the need to support more robust remote grids. Despite the economic case for renewable energy in remote areas, many of the case study areas required public grants and other incentives in order to realize their renewable energy systems (see El Hierro, Coral Bay, Miyako, and Kodiak case studies). This reflects a range of factors, including that renewable energy economics were not as strong when some of these projects initially launched, that there was a lack of available and/or accessible private capital, and that the costs of system design and planning were comparatively high given the pilot nature of many of the installations. Even with traditional generation technologies the costs of power are higher in remote areas, which enhances and enables renewables to undercut diesel and other remote generation from fossil fuels.

Renewable energy system costs in remote areas must be viewed within the context of the broader system plan. It is important to recognize that the renewable energy installations were part of an integrated hybrid system and that financing is frequently required to support the upgrade and build-out of the grid, including storage, controls, etc., and not just the renewable energy generators alone. In many cases, the renewable generators provide a more cost-effective solution to what would normally occur under other grid expansion or rural electrification initiatives. The recognition of the need to view the costs of the renewable generators within the context of the larger system plan and community requirements was a common theme in almost all case studies (see Akkan case study).

Research and development budgets can support projects in remote areas. Given the innovative nature of many renewable energy systems in remote areas, they can often be justified as research and development projects, such as in Miyakojima, El Hierro, and Ramea. This can create an additional source of funds.

Public funds have been used to leverage private funds under different models. When public entities bear part of the upfront costs, private sector entities have been able make investment in remote areas in different ways. Public support, for example, attracted a 10% private investment share in El Hierro (see case study). As discussed above, public funds have been used to leverage community equity investments in Eigg, Faroe Islands, and in Akkan. Public funds are not always necessary, however.

Fuel subsidies have an important impact on project financing. Remote areas with high conventional energy subsidies and/or artificially low energy prices required a higher share of public resources to realize the projects. In the absence of fuel subsidies, private companies can successfully create a high-penetration renewable system with comparatively minimal governmental incentives. The Bonaire project was financed primarily by a private bank using a mix of debt and equity. The project appears to be
proving a strong investment, although the project faced high wind turbine capital costs and financial challenges when one of the initial project partners went bankrupt.

**Development risk can create a substantial barrier to renewable energy systems in small communities.** Renewable energy in remote areas can often include not only the costs of the renewable energy systems, but the costs associated with the potentially complex task of planning the integration of the systems with existing infrastructure and securing the upfront community buy-in, permits, utility approvals, etc. This degree of complexity can be daunting in non-remote areas, let alone in remote areas. It not only discourages potential developers but also complicates financing. In Eigg, for example, the community was reluctant to begin the project since they faced the high risk of paying for the initial design of system before making investment.

### 3.2.7.5 ENVIRONMENTAL LESSONS LEARNED

**RETs can achieve environmental goals of remote areas.** RETs can improve the environment in areas that provide tourism (see Floreana, Bonaire, and El Hierro case studies), and help preserve pristine locations near important research areas (see Ross Island case study). Reducing reliance on diesel and other fossil fuels in these areas can also help reduce the incidence of spills, of air pollution or other forms of contamination that can impact these ecosystems. See Section 3.1.8. on environmental considerations in remote areas.

**Extreme weather events must be pondered when installing RET.** Local climatic conditions – in particular extreme weather events – should be considered when selecting the technologies and their design. For example, to prevent damage during typhoons, Coral Bay used a turbine design that can lay down flat (see Coral Bay case study), and Miyako Island installed PV with a lower tilt (see Miyako case study). The Faroe Islands have recommended wind turbines and solar hot water heater designs that can handle their high speed winter winds (see Faroe Island case study). The logistics and planning can also be influenced by extreme weather, and planning schedules should consider this. For example, in areas with long winters the installation schedule may be impacted by ice in winter (see Ross Island and Kodiak case studies). Another important environmental consideration is the presence of bird migratory pathways, which can limit the use of certain technologies, or impact their siting.
4. FINANCING

There has been a rapid and sustained increase in the amount of financial investment in renewable energy during the past several years, despite the recent global financial crisis (Fritz-Morgenthal et al., 2009). This increase has been accompanied by an effort to track and report on renewable energy investment trends. In 2010, a total of $211 billion (€161 billion) was invested globally in renewable energy, a 32% increase over 2009 (McCrone et al., 2010; 2011). While large-scale projects have dominated renewable energy investments during the past decade, 2010 saw a surge in smaller projects. Small-scale renewable electricity generation under 1 MW accounted for $60 billion (€46 billion) of the total in 2010, up 90% over 2009. It is also estimated that solar water heating systems accounted for an additional $10 billion (€7.6 billion) in investment (McCrone et al., 2011).

Despite the improvement in financing statistics and the explicit tracking of small renewable energy systems, little data is available on investment needs or trends for renewable energy in remote communities. The global trends make it clear, however, that renewable energy finance has expanded dramatically. A key question for policymakers is whether (and if so, how) these new opportunities can begin to be replicated on a wider scale in remote communities.

Renewable energy faces a range of barriers to accelerated deployment worldwide. These can be broadly characterized as economic and non-economic barriers (Ölz, 2008). Non-economic barriers, which include issues related to technology, administrative complexity, social and cultural opposition, and lack of human capital among others, have been discussed extensively in recent studies, including the RENBAR report (ECORYS, 2010; IEA-RETD, 2011). The non-economic barriers that are particularly prominent in remote areas are discussed in Section 3.1 and also explored in the case studies in Appendix A.

In contrast, economic barriers include a host of interrelated challenges such as the high upfront cost of renewable energy systems, the development of credible revenue models that enable projects to access financing, and the difficulty in obtaining low cost financing (particularly for early stage feasibility and construction work). **Compounding the economic barriers in remote areas is the fact that diesel-based electricity systems are often already in place, making it difficult for any new projects (particularly those with high upfront costs) to displace existing generation even when relatively near-term fuel savings benefits can be demonstrated.**

A wide range of reports address topics related to renewable energy finance, such as the sources of finance (DBCCA, 2011), evaluations of different finance mechanisms (de Jager et al., 2010), financial structures for renewable energy projects (Harper et al., 2007), finance and microfinance in developing countries (Gregory et al., 1997; Morris et al., 2007), the interaction between finance and the cost of capital (de Jager and Rathmann, 2008), and investor perspectives on renewable energy policy (Bürer and Wüstenhagen, 2009; DBCCA, 2009b; von Flotow and Friebe, 2011), among others. This section draws on

---

43 The IEA (2010) estimates that up to $5.7 trillion in new investment will be needed between 2010-2035 in order to respond to current climate and energy challenges, echoing similar estimates from several other sources (e.g., Woodhouse, 2005).
these sources to explore the opportunities and challenges to financing renewable energy in remote areas.

In particular, this chapter focuses on the question of whether recent diesel fuel price trends create an opportunity to finance renewable energy without public subsidies. As described in the case studies in Appendix A, remote areas thus far have relied heavily on public sector subsidies to develop energy infrastructure, and this applies both to conventional and renewable technologies. Most RETs in the case studies were deployed either as demonstration, RD&D, or proof-of-concept projects, and benefited from varying degrees of public support. However, with renewable energy costs coming down worldwide, the foundations may be shifting, and many remote area projects may now be financeable on a stand-alone basis.

The first part of the section deals with issues that influence the cost of capital, including investment risks and how they differ in remote areas. In general, due to the unique nature of remote area projects (smaller size, higher operational and construction risks, etc.), the cost of capital to finance projects will tend, on average, to be higher than for mainland projects deploying the same technologies. This is an important factor to consider, regardless of how the projects are financed. The second part reviews recent energy price trends as well as their implications for the competitiveness of different energy technologies. The third part of the section then discusses the distinguishing characteristics of remote areas from a financing perspective, with a focus on public subsidies, and the availability of capital. As is the case throughout the report, we acknowledge that it is challenging to discuss remote areas generally and comprehensively, due primarily to site-specific considerations such as social, cultural and institutional influences. As a result, this section is intended as a broad supplement to the discussion of specific categories contained in Section 3.2.

4.1 COST OF CAPITAL

At a high level, there are three main factors influence the costs of a renewable energy project: (1) the investment or capital cost (capital expenditures, or CapEx) of planning, procuring and installing the system; (2) the ongoing operations and maintenance costs (OpEx); and (3) the costs of financing the system ("FinEx"). Typically, more attention is paid to the CapEx and OpEx costs of RE systems, than to financing. FinEx refers to the terms and costs of financing, both the cost of capital and the transaction costs associated with the time, expenses and due diligence required to secure financing. These factors can be significant for remote area projects, which are generally smaller in size, and are exposed to greater uncertainties, and risks.

The cost of capital reflects the perceived risk of a renewable energy project; it includes both the interest rate charged for debt as well as the rate of return required on equity. The high upfront cost of RE projects makes them highly sensitive to the initial cost of capital. As a result, financing costs play a critical role in determining the initial affordability, competitiveness, as well as the levelised costs of RE projects (de Jager and Rathmann 2008).
To illustrate the influence that the cost of capital can have on remote area projects, Figure 10 presents a hypothetical case developed using HOMER software and showing the percentage of renewable and diesel generation that would be provided in a 10 kW remote system. The projection assumes a good solar resource, a typical remote area load pattern, and a cost of diesel fuel of US$1.50 per liter (€1.15 per liter). The horizontal axis indicates a range of interest rates (which serve as a proxy for the cost of capital to the project sponsor). The vertical axis indicates the PV array capacity that could cost-effectively be installed to supply the 10kW system.

![Figure 10: Percent Renewable Energy Penetration in a 10 kW System (Source: HOMER simulation)](chart)

As this chart highlights, the amount of RE penetration that can be cost-competitively developed begins to fall dramatically as the interest rate exceeds 10%. Renewable energy is simply not cost-competitive with diesel at costs of capital above 15%. The cost of financing for the system plays a crucial role in determining the overall cost-competitiveness of RE systems in relation to conventional, diesel-powered grids. This underscores one of the potential areas in which policymakers can assist renewable energy investment in remote areas, by providing targeted programs or policies aimed at lowering the cost of financing.

### 4.2 RISK MITIGATION

Reducing the cost of capital in remote areas by mitigating key risks can help unlock renewable energy financing. Moreover, lower costs of capital translate directly into lower project costs and therefore reduce the subsidy levels required (if any) for energy resources. The cost of capital is closely linked to:

- **The availability of capital** – in areas with deep and highly liquid capital markets, there may be several potential investors vying to finance a particular project. This competition can benefit project developers, who benefit from a lower cost of capital, offered on more favorable terms.
Conversely, a more limited pool of capital providers can drive up the cost of capital. During the recent financial crisis, for example, the number of tax equity investors active in the US declined from 20 to 4 between 2008 and 2009, which along with other factors caused a sharp increase in the cost of equity (Karcher, 2008; Schwabe et al., 2009). As discussed above, there may not be a large pool of capital providers in remote areas.

- **The type of capital available** - public debt (e.g. general obligation bonds or revenue bonds), for example, can be significantly cheaper than commercial debt, whereas commercial debt is cheaper than equity.

- **Risk perception** - Remote area projects tend to face a more diverse, and in many cases more acute, set of risks than projects in mainland areas. Where the risks are high, the cost of capital will tend to be higher – this suggests that one of the ways in which governments can help increase the competitiveness of RE is by reducing project risks (de Jager and Rathmann 2008, Deutsche Bank 2010, Corfee et al. 2010).

The remainder of this section focuses on the relationship between risks and the cost of capital in remote areas. Table 8 provides an overview of the different kinds of risks that renewable energy projects face, with specific consideration given to how these relate to remote areas (Corfee et al., 2010; de Jager and Rathmann, 2008; Justice, 2009).
### Table 8: Various Forms of Project Risk and Potential Mitigation Strategies

<table>
<thead>
<tr>
<th>Applicable Questions and Considerations</th>
<th>Special Considerations for Remote Areas</th>
<th>Potential Mitigation Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Timing Risk:</strong> Will the project milestones be met, and built on time?</td>
<td>Remote areas are more likely to experience delays in development because of their geographic remoteness.</td>
<td>Establish flexible timelines</td>
</tr>
<tr>
<td><strong>Force majeure risk:</strong> is the project exposed to major weather events, earthquakes, etc.?</td>
<td>Considerations include delays in delivery of components can, the need to provide training to build local capacity, the need to rely on outside experts, etc.</td>
<td>Setting realistic goals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop training programs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collaborate with stakeholders early and often</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Factor in force majeure exposures in project siting</td>
</tr>
<tr>
<td><strong>Construction Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Delays and possibility of cost overruns</td>
<td></td>
<td>Establish a clear project plan</td>
</tr>
<tr>
<td>- Will construction contractors deliver?</td>
<td>Remote areas are likely to face higher construction risks, due to decreased availability of materials, labor, and components</td>
<td>Line up contractors and material well ahead of project construction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop local sources of materials and labor where possible</td>
</tr>
<tr>
<td><strong>Revenue Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Price Risk:</strong> What price is the electricity sold for? Inflation?</td>
<td>Price contracts in remote areas may be more difficult to secure, depending on the structure of the energy system</td>
<td>Establish and enforce PPAs</td>
</tr>
<tr>
<td></td>
<td>Counterparties in remote areas – i.e. the utility or business purchasing the power – may not be creditworthy or able to pay</td>
<td>Adopt an avoided cost-based formula linked to diesel</td>
</tr>
<tr>
<td><strong>Performance Risk:</strong> Will the project perform as expected?</td>
<td>Weather and other factors can disproportionately impact remote areas (hurricanes, tsunamis, etc.)</td>
<td>Local training can reduce down-times and improve performance</td>
</tr>
<tr>
<td><strong>Counterparty Risk:</strong> Will the off-taker be able to pay?</td>
<td></td>
<td>Design projects will force majeure risks in mind</td>
</tr>
<tr>
<td>Applicable Questions and Considerations</td>
<td>Special Considerations for Remote Areas</td>
<td>Potential Mitigation Strategies</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td><strong>Operational Risk</strong></td>
<td>- How reliable is the project?</td>
<td>- Establish a clear project plan</td>
</tr>
<tr>
<td>- Is there expertise on hand to repair?</td>
<td>- The reduced availability of on-site engineers can increase down-times and introduce additional revenue risk for investors, and compromise reliability</td>
<td>- Align all partners ahead of time</td>
</tr>
<tr>
<td></td>
<td>- The lack of readily available spare parts in remote areas is a risk to project operation</td>
<td>- Establish “troubleshooting-at-a-distance” with experts via phone or voice-over-internet</td>
</tr>
<tr>
<td><strong>Political / Country Risk</strong></td>
<td>- Can assets be expropriated?</td>
<td>- Foster greater local governance; officials living directly in remote areas have the clearest incentive to keep systems operating</td>
</tr>
<tr>
<td>- Are there risks of upheaval, political instability, coups, etc?</td>
<td>- Some remote areas may have governance structures, which may exacerbate perceived political risk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- The absence of institutions (e.g. credible PPAs, legal framework, etc.), such as many in developing countries, can increase country risk</td>
<td></td>
</tr>
<tr>
<td><strong>Currency Risk</strong></td>
<td>- Currency Risk: Does not only apply to remote areas, but can be important, particularly in developing countries.</td>
<td>- The scale of currency risk will depend on the status of the central government</td>
</tr>
<tr>
<td>- Is there a credible risk of currency devaluation?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some of these risks may influence capital availability. In remote areas with excessive political risk, for instance, there may be no investors willing to provide capital. Other risks may not constrain availability, but may lead investors to require a significantly higher rate of return. A recent study by Deutsche Bank, for example, concluded that the presence of technology risk, political risk, currency risks, and regulatory risks could move the return expectation for an infrastructure investment from 8% to over 20% (DB Climate Change Advisors, 2011). And as highlighted above, the cost of capital can have a significant impact on the cost-competitiveness of RE investments.

When the array of project risks is articulated explicitly in this way, it becomes easier to appreciate why financing projects in remote areas poses unique challenges. Not only is private capital likely to be more expensive to obtain, its availability is also likely to be constrained. Many lenders and investors may simply consider remote area projects to be too risky, and the project sizes to be too small. A key implication of this is that efforts to encourage greater private investment will stand a greater chance of success if certain key risks are mitigated, and if projects can be aggregated. Targeted risk mitigation can be seen as an important way in which governments and the public sector more broadly can improve the attractiveness of remote area projects.

There is a wide variety of ways in which public sector resources can be marshaled to reduce the costs of capital by addressing or mitigating key risks. These include:

- Technical assistance to address non-economic barriers related to project transaction costs or the lack of local expertise
- The design of low-risk renewable energy policies that facilitate project finance. IEA-RETD research has concluded that policies for renewable energy can lower the levelised cost of renewable systems by 10-30% when compared to environments without supporting policy (de Jager and Rathmann, 2008). These reductions could theoretically be greater in remote areas, where a higher risk premium would normally apply.
- The use of de-risking mechanisms such as guarantees or insurance to reduce the costs of equity, concessional loans to provide low cost debt, and/or other direct incentives such as grants to reduce system costs (DB Climate Change Advisors, 2011).

The table below summarizes some of these mechanisms and their pros and cons with regard to remote areas:
<table>
<thead>
<tr>
<th>Financial mechanism</th>
<th>Definition</th>
<th>Pros and cons</th>
</tr>
</thead>
</table>
| **Credit line**                 | Provides a line of credit to local banks with which they can on-lend to remote communities | **Pros:** Builds confidence and capacity of local financing institutions to lend to clean energy projects in their communities.  
**Cons:** In many such programs, banks focus on large, commercial loans and do not serve smaller-scale investments needed in remote areas                                      |
| **Guarantees**                  | There are a broad range of different guarantees that could be applied in remote areas, including guarantees for project loans, guarantees that utilities will pay projects, etc. (Mostert et al., 2010) | **Pros:** Government does not have to pay if the project is successful.  
**Cons:** Reduces banks perceived risk of projects that are otherwise “ready to go” but for lack of financing; does not address real underlying risks. |
| **Loan funds**                  | Governments or utility funds established to make loans to entities at more favorable terms – such as lower interest rates or longer tenors – than they would otherwise be able to secure. | **Pros:** Enables a broader range of projects to secure financing and can enable access to capital in remote areas without well established financial institutions  
**Cons:** There are constraints to the scalability and sustainability of loan program. These may be less of a concern in remote areas, however. |
| **Loan buy-down programs**      | Governments provide funds to banks in order to reduce the interest rates at which banks will lend. | **Pros:** Enables access to capital at lower costs than would otherwise be available.  
**Cons:** May not address the issue of capital availability and may create funding competition for other programs (e.g. direct grants) |

4.3 RENEWABLES AND COST-COMPETITIVENESS

As discussed in Section 2, while most renewable energy technologies are now broadly competitive with diesel generation, the high upfront costs of renewable electricity remain a significant barrier to wide deployment in remote areas. As can be seen in the graph below, the capital costs of renewable energy systems represent a large share of a project’s levelised cost of generation. By contrast, diesel generators have low capital costs. If project developers do not have a ready source of capital, diesel generators may be more “affordable” in the short term than renewable generation even though they result in higher costs over time. This is where financing can play an essential role: it can be used to overcome this challenge by providing the needed capital upfront, helping to unlock the long-term savings. For governments that subsidize fossil fuels in remote areas, a one-time investment in renewable energy assets could reduce long-term fuel liabilities, and significantly reduce the annual budgetary allocations required to support remote communities.

4.3.1 CONSIDERATIONS FOR FINANCING RENEWABLE ENERGY IN REMOTE AREAS

This section reviews each of the barriers introduced above: the role of subsidies, availability of capital, access to capital, and the cost of capital in greater detail. It includes discussion of potential mitigating measures or solutions that could be used to address these barriers.

4.3.2 THE ROLE OF GOVERNMENT SUBSIDIES

Remote communities often face the dual challenge of high energy costs and low-incomes when compared to non-remote communities (Wade, 2005). In order to alleviate the disproportionate burden borne by remote areas, policymakers often provide subsidies on the price of diesel fuel and/or on the price of electricity in order make energy more affordable. In both IEA-RETD member countries (e.g. Japan, France) and beyond, for example, electrical utilities are mandated to sell power in remote areas at the same rates that they sell power in non-remote areas. These subsidies provide important economic benefits in remote areas where residents might otherwise not be able to afford the “true” energy costs of electricity generation. At the same time, however, these subsidies weaken the competitive position of renewable energy and can help entrench remote areas’ dependence on fossil fuels.

Another form of government intervention that can be self-perpetuating in remote communities is the use of government subsidies to support renewable energy. In non-remote areas, private sector investment in renewable energy is seen not only as a means to leverage limited public funds, but as a necessity for achieving the investment levels required for climate stabilization (Milford et al., 2011). In remote communities, however, renewable energy projects have been financed in large part (often entirely) by governments, either as pilot projects or as part of electrification efforts designed to better harness local resources (e.g. local rivers). As renewable energy in remote areas moves beyond the pilot phase, however, and towards broader deployment, public sector funds may “crowd out” private sector investors who cannot compete with a government treasury offering no- or low-interest public funds. While this is not technically a barrier, it can impede the participation of individual or private sources of financing. If attracting private financing is considered desirable, and becomes an explicit policy objective
with regard to remote areas, policymakers will need to consider how public funds can most appropriately be “ramped down” to make room for private investment.

Alternatively, the possibility for innovative partnerships, cost sharing arrangements, pay-for-service contracts, and other forms of private-public partnerships may provide the greatest flexibility, and the greatest potential to cost-effectively leverage public resources in remote areas. As the case studies demonstrate, islands like Ramea in Canada and the Faroe Islands have succeeded in developing remote area projects by making use of a combination of public and private dollars, including grants, economic development funds, as well as private sector and utility investment. In light of the sheer diversity of remote areas worldwide, the respective roles and responsibilities of government and the private sectors needs to be determined on a case-by-case basis.

### 4.3.3 CAPITAL AVAILABILITY AND ACCESS

A broad range of different entities can potentially invest, or provide capital, in renewable energy in remote areas. These could include commercial lenders such as banks and credit unions, utilities, and private equity providers, among others. The presence of different types of investors in different market varies widely and depends on factors such as financial regulations, electricity market structure, and potential market size, among others. However, some areas may be unable to access traditional lending from a bank. For instance, many communities in Canada have strict debt caps, which limits their ability to borrow in this way. Also, some regions prohibit borrowing for certain kinds of ventures, which can limit the ability of such remote communities to make use debt to finance projects.

Note that this section does not attempt to align different capital providers with different categories of remote areas. Instead, this section broadly discusses the issues of capital availability, or the presence of capital providers willing and able to invest, and access to capital, or the ability of renewable energy projects to secure capital investments, in remote areas.

#### 4.3.3.1 CAPITAL AVAILABILITY

Broadly speaking, the two primary types of investment capital are debt and equity. Depending on the area in question, both debt and equity may be in short supply.

**DEBT FINANCE**

Debt finance refers to a loans provided to a renewable energy project that must be repaid over time, no matter what the project outcome. Borrowers must repay both the original amount of the loan (the principal) as well as interest. Banks typically serve as lenders, although state and local governments can also provide public debt by issuing general obligation bonds or revenue bonds (Cory et al., 2008).

The availability of debt will depend largely on local conditions. Some remote communities may have well-capitalized debt providers that are already active in renewable energy finance. The banking sector in Barbados, for example, actively provides loans for solar thermal systems (Doyle et al., 2003). In smaller
or less accessible remote areas, however, there may not be an available debt provider. The lack of active lenders can create a “chicken and egg” problem where there is not a sufficient pipeline of renewable energy projects to attract capital, and the lack of capital prevents the formation of a pipeline of projects (DBCCA, 2010). Even if lenders are active in given remote area, they may not be willing to be “first” to invest before renewable energy projects have a demonstrated track record of success.

### EQUITY FINANCE

Equity finance refers to the practice of selling an ownership interest of a renewable energy project to investors. Equity is generally more expensive than debt for a number of reasons: first, the repayment is less reliable, because equity investors are paid only after debt providers (i.e. they are "subordinated"). What this means in practice is that the revenue stream is less reliable, which translates into a higher interest rate. Second, equity investors generally have no claim on the assets of the project in the event of a bankruptcy; this puts the equity provider at risk of losing everything if the project fails. Third, equity investors typically have a higher risk tolerance, which means they will generally invest in projects or project stages (e.g. the development or construction phase) that debt providers would not. Due to their higher risks, such projects or ventures command a higher rate of return. Equity providers can include individuals or companies providing their own capital, venture capital funds, and private equity funds, among others (Justice, 2009). This situation becomes even more challenging for projects in remote areas, due to the higher risks that such projects typically present.

The availability of equity is highly dependent on local conditions and also the types of projects that need to be financed. Small-scale projects, such as home PV systems, may depend heavily on equity contributions from individuals. A 2009 survey of residential PV systems in the US, for example, found that 67% financed the systems entirely with cash, while only 21% utilized a home equity loan (Hossain et al., 2009). Individuals in many low-income remote areas may not have the cash required to pay for renewable energy systems outright. There may also not be equity available for non-residential renewable energy systems. In areas served by monopoly utilities, the utility typically uses its own equity to finance new generation projects. When equity is not available, utilities often opt to purchase power from independent power producers (IPP), who may be better positioned to secure private equity investment. In remote areas that lack utility equity but also do not allow IPPs, the number of potential equity providers may be limited.

### 4.3.3.2 ACCESS TO CAPITAL

Access to capital is widely recognized as one of the primary barriers to renewable energy deployment (Milford et al., 2011). As a result, this section focuses specifically on some of the financing options that

---

44 In some developing countries, there might not be an established banking sector or a familiarity among local populations with banking practice. Energy microfinance programs, coupled with technical assistance, capacity building, training, and awareness campaigns have had notable successes electrifying remote areas in several countries (Morris et al., 2007; Murthy et al., 2009)

45 This notwithstanding, certain remote areas may have potential equity providers in the form of local hoteliers, expats, or even the offshore fund manager community in areas such as in the Cayman Islands, Bermuda, or any of a number of areas recognized as offshore financial centers. However, this provides an unreliable and at-best partial solution to the provision of equity finance in remote areas – expats and others may play a role in certain regions, but this is not likely to be widespread.
can be used as solutions to this challenge. The issue of access to capital is closely related to the issue of capital availability. Access to capital implies that capital is not only available, but that the projects that require capital are able to secure it. This section briefly considers access to capital as it relates to the commercial and residential sectors.

COMMERCIAL FINANCING
Financing for commercial energy projects can be broadly characterized as corporate finance or project finance.

Corporate finance, or balance sheet financing, involves using a company’s assets to purchase and own a renewable energy system outright using a mix of corporate equity and debt. The benefits of balance sheet financing include a potentially lower cost of capital because the cost of capital is assessed based on the risk profile of the company as a whole, rather than the economics of the particular project. Balance sheet financing may be constrained in general, however, by the fact that renewable energy may not be the core business function of the company in question and may therefore require a steep learning curve and require renewable energy to compete for internal resources with other priorities (Bolinger, 2009). In lower income or smaller remote areas, balance sheet financing may be further constrained by the fact that potential investors may lack the resources required to invest in projects.

Project financing, or limited recourse financing, uses the cash flows generated by the renewable energy project to repay debt from a third party (e.g. a bank). Project finance moves the project “off balance sheet” and requires the project to demonstrate that it can operate on its own merits (i.e. pay back investors using its own revenues). Project finance relieves the need for project developers to provide significant amounts of upfront capital. However, lenders typically specify a threshold below which they will not provide capital for project finance (e.g. $30 million or €23 million). This threshold is a barrier to project finance in remote areas since remote area renewable energy projects are typically far below these minimums. It is possible to aggregate small projects into portfolios large enough to project finance using standard terms, conditions, and contracts. Although there have been proposals made to aggregate remote communities (Ackermann et al., 2009), such strategies have not been widely pursued to date.

CONSUMER/RESIDENTIAL FINANCING
The landscape for financing at the consumer or residential level contrasts sharply with commercial financing options. The range of available financial mechanisms is limited and it can be difficult for consumers to secure financing for renewable energy projects from banks. Residents must demonstrate that they have good credit and must typically provide a sizeable down payment. In addition, some banks may specify that residents provide additional collateral, such as a vehicle or other property. Such requirements may be too onerous for residents in remote communities to meet. Aboriginal communities in Canada, for example, have little collateral that they can use to secure debt in particular because federal law prevents liens against land of First Nations’ land. Also, the market value of housing or other assets in remote areas (particularly in the north) may be considered less reliable than in mainland communities.

---

46 This depends on the entity in question. The costs of capital for corporate financing may not be more attractive than the cost of other alternatives.
regions. This provides only a brief glimpse of the issues in securing consumer or residential financing in remote areas. However, there are cases where such forms of funding will be the only source available.

4.3.3.3 INTERNATIONAL SOURCES OF FUNDING

In addition to debt and equity from traditional sources, remote communities may be able to access funds from international sources. Remote communities in developing countries, for example, can access funds from international agencies and banks. The amount of international development lending to clean energy projects increased from $6.5 billion (€5 billion) to $21.1 billion (€16.1 billion) (de Jager et al., 2010). Renewable energy for remote areas in developing countries have benefitted significantly from international grants and loans. As discussed above, however, there is concern that public sector resources be deployed so as not to crowd out private participation in international markets (Glemarec, 2011).

Another potential resource may be the use of climate finance to support renewable in remote communities. According to research from the IEA-RETD LINK, international climate finance mechanisms such as the Clean Development Mechanism (CDM) has increasingly been used to support renewable energy development as “low-hanging” industrial greenhouse gas mitigation projects have been exhausted (Castro et al., 2011). Climate finance is unlikely to emerge as a near-term solution for remote communities for several reasons. First, the transaction costs associated with CDM have limited the ability of small-scale projects to participate (Figuieres, 2006; Jacobs et al., 2009). Second, there is currently uncertainty about the long-term future of the CDM following as the recent Durban Climate Change Conference (DB Climate Change Advisors, 2012; van Melle et al., 2011). Finally, new sources of funding such as the Copenhagen Green Climate Fund (which is to be capitalized with $100 billion or €76 billion annually by 2020) are under development, but there remain uncertainties related to capitalization, structure, and implementation of these new funds (DB Climate Change Advisors, 2012; Liebreich, 2011). It is unlikely that remote communities will be able to access these new funds at least for the next several years.

It is further not likely that remote communities in IEA-RETD countries, or other developed countries, will be able to access many sources of finance from international development sources or carbon markets because they are only available to developing countries.

The voluntary carbon market, however, may provide a potential source of international finance for renewable energy in IEA-RETD remote communities. The voluntary market is sustained by entities that purchase carbon directly or that participate in voluntary exchanges in order to meet internal carbon reduction targets. The voluntary market grew 34% from 98 to 131 million tons of CO2 equivalent between 2009 and 2010, and market value grew from $415 million (€317 million) to $424 million (€324 million). Of this, 20% was for renewable energy projects, and 6% was for small and micro sized projects (both energy and other) (Peters-Stanley et al., 2011). The amount of small or micro projects supported through the voluntary markets more than tripled between 2009 and 2010 based on specific demand from buyers for smaller and “charismatic” projects. This trend indicates that there may be opportunities

47 As of June 2011, for example, only 15 CDM projects representing 0.2% of total projects targeted improved energy access at the household level (International Energy Agency, 2011)
for increased use of voluntary carbon markets to support renewable energy in remote communities. Bonaire, for example, is currently seeking voluntary carbon finance for a wind farm (Johnstone, 2010). Voluntary market prices remain comparatively low (e.g. approximately $4-$5/ton (€3-€3.8/ton) in the Asia, Latin America and Asia, and approximately $10-$20 (€7.6-€15.2) in Europe and Oceana), however, and it is unclear how significant the impact of carbon revenues would be on jumpstarting new development (Peters-Stanley et al., 2011).

4.3.3.4 PUBLIC RESOURCES TARGETING CAPITAL AVAILABILITY, ACCESS AND COST

Renewable energy may be theoretically cost-competitive with diesel generation, but remote communities may face barriers related to capital availability and access to capital that will constrain the ability to finance renewable energy without some kind of public sector involvement. Even if policymakers have a goal of reducing the public sector share of renewable energy finance, ongoing involvement is likely to be required in order to create the conditions for new capital providers to enter the market, encourage capital providers to support projects that they may be unfamiliar with, and/or enable constituencies that might otherwise not be able to secure financing to do so. There are a range of different policy tools that can be applied to increase the availability of both debt and equity in remote areas, such as loan guarantee mechanisms, loan programs and the creation of dedicated energy equity funds (see Table 9 above).48

4.4 INNOVATIVE BUSINESS MODELS

As discussed in the previous sections, public sector resources and targeted renewable energy policies may be required to create an enabling environment to scale-up renewable energy financing in remote areas. An additional strategy for overcoming some of the barriers to finance may be the development of new ownership and financing strategies for renewable energy in remote areas.

Renewable energy ownership is often closely related to the ownership structure of the energy system. There is currently a range of different energy system ownership and operational models in place in the IEA-RETD community, including, for example, state-owned utilities (e.g. Martinique), private utilities (e.g. Curacao), and community-based energy providers (e.g. Island of Eigg). Different energy ownership models and their pros and cons have been explored recent reports (Houghton, 2010; Reiche et al., 2006; Wade, 2005; World Bank, 2008). This section focuses specifically on alternative ownership models that may improve access to finance.

The benefit of alternative ownership and finance models is that they may open up new avenues of access to finance and they may also mitigate project risks by transferring them to entities that are more capable of managing them.

48 The CAPE Fund in Canada (http://www.capefund.ca/), for example, is a $50 million private-sector fund that focuses exclusively on investing in Aboriginal ventures, including renewable energy projects, which might otherwise have difficulty securing private equity.
4.4.1 ENERGY PERFORMANCE CONTRACTING (EPC)

Performance contracting refers to the practice of financing energy upgrades, renovations, or rehabilitations based on the energy savings that the measures will generate (Hansen, 2005). Third-party energy service companies (ESCOs) typically offer to identify energy savings measures at non-residential buildings and then arrange for those measures to be paid for (i.e. financed) and installed. The building owners then agree to pay the ESCO back utilizing the savings generated. ESCOs will typically guarantee that a certain amount of savings will be realized. Performance contracts transfer much of the operational risk of the energy savings measures from the system host to the ESCO. The involvement of the ESCO may also enable access to new sources of financing (e.g. capital provided by the ESCO’s parent company or through the utility). Performance contracts have historically been used primarily for energy efficiency and conservation measures. It is possible, however, to integrate renewable energy, such as solar thermal systems, PV or wind power, into performance contracts (Rickerson, 2004) and an increasing number of performance contracts in major markets are incorporating renewables (see, e.g. Bertoldi et al., 2007; Satchwell et al., 2010). Blending renewable energy and energy efficiency in the same performance contract enables the savings from quick payback technologies such as lighting to effectively buy-down the cost of longer-payback renewable energy technologies. Performance contracts may be an option for some remote areas, but not for others. A barrier to performance contracts in remote areas is the fact that project sizes might be too small or too geographically remote for private ESCOs to engage in. The IEA-RETD BIZZ project notes, for example, that EPCs can be as low as $100,000 (€76,000), but are typically an order of magnitude higher (Würtenberger et al., 2011). Nunavut in Canada is currently pursuing performance contracts for public buildings in its capital and will be expanding the program to governments in other cities and towns (Northern Premiers’ Forum, 2011).

4.4.2 FEE-FOR-SERVICE MODELS

Under fee-for-service models\(^{50}\), electric utilities (private and public) or 3rd party providers maintain ownership of the renewable energy system and enter into either a power purchase agreement or a lease arrangement with the system host. In the first case the utility or ESCOs will invest in the system and directly sell the energy to the customer at a price comparable (or lower to) retail energy rates. For leased systems, the consumer gradually pays for the systems installed by a utility or another third party owner, until it is fully paid; the utility recovers its investment while the consumer benefits from lower electricity bills. Fee-for-service models have long been proposed for solar water heating (Guiney et al., 2006; Lyons and Comer, 1999) and have been implemented by several utilities in the US (Richmond et al., 2003) as well as by renewable energy service companies in developing countries (Mercados, 2010; Wade, 2005). Third-party ownership models have been particularly successful for financing photovoltaics in the US, and drove a significant amount of new commercial capacity in recent years (Bolinger, 2009; Cory et al., 2008; Guice and King, 2008). More recently, third party ownership of residential systems has emerged as a major driver of market growth in several US states (Coughlin and Cory, 2009). Fee-for-service models do not face the same minimum scale thresholds as energy performance contracts. An emerging

\(^{49}\) ESCOs may also offer shared savings agreements under which the ESCO and the client building will agree ahead of time to share the savings generated by the project. These arrangements have been controversial in the past, however, when the stipulated savings have not been realized.

\(^{50}\) Fee-for-service models also include energy supply contracting and “chauffage” (i.e. heating) contracts (Walker, 2001).
A model called integrated energy contracting (IEC) combines fee-for-service models with energy conservation measures that are not supported by a full performance guarantee and therefore can be implemented at smaller scales with lower transaction costs (Würtenberger et al., 2011). The IEC model is currently being piloted in Europe and could also be piloted in remote areas.

For remote communities, an alternative ownership structure is the remote-specific utility or Remote Area Energy Service Company (RESCO). RESCOs are quasi-governmental organizations that provide electricity and other services in remote communities. RESCOs can raise comparatively low-cost financing by using mechanisms such as bonds and can therefore provide lower cost electricity than private sector actors. A public board typically oversees them, and commissioners are elected from the community or municipality. The RESCO maintains ownership of the renewable energy facilities, the company provides installation, operation, maintenance, repair, and additional services to end-users in return for monthly fees for connection and service (Magda Moner-Girona, 2008). Case study communities that employ a RESCO include Eigg Island, Faroe Island Nólsoy Project, Akkan Morocco, and Floreana.

The feasibility of alternative ownership and financing mechanisms such as performance contracts and fee-for-service models will depend on the project economics, energy system structure, and regulatory environment of each remote area. As noted in IEA-BIZZ, the introduction of policies such as feed-in tariffs can also support new ownership structures. As discussed in Text Box 4 below, however, FiTs in remote areas may require customized designs. **Introducing new ownership models, or working with incumbent energy service providers to introduce new ownership models themselves could open new avenues for renewable energy introduction** and for fossil fuel subsidy reduction.

### 4.5 CONCLUSION

In many remote communities, capital availability, access, and cost will remain constraints on private financing of renewable energy projects. This underscores several points about the role and potential responsibilities of governments in facilitating private financing for remote area projects. First, it is likely that public sector resources will be required to support renewable energy in remote areas, despite the promise of cost competition with diesel. Second, there is a range of different public sector tools available to support renewable energy, such as R&D funding, in-kind support, technical assistance, related infrastructure investment, loan guarantees, and worker training programs. Rather than providing direct cash investments, for example, governments may can address the non-economic barriers to project development by strengthening the institutional framework, clarifying the role and responsibilities of the existing utility (where applicable), assisting with local skills training, and providing protections against political risk. These non-monetary, de-risking mechanisms can go a significant way toward supporting and facilitating remote area investment, either by increasing the availability of capital, and/or by reducing its cost. Governments can also target reductions in the cost of equity capital through financial mechanisms such as concessional loans or guarantees.

**Governments can also play a role in supporting renewable energy by removing or scaling back fossil fuel subsidies.** The two efforts can be mutually reinforcing. **In certain areas, the continued subsidization of fossil energy sources represents one of the chief barriers to the wider adoption of renewable energy**
technologies. In order to move toward more integrated policymaking, and to avoid what may be called policy ‘dissonance’, it is necessary to look at the full suite of existing subsidies and supports offered to energy technologies, and make decisions in light of all the facts, and with a view to the true costs of different energy paths.

In many cases, renewable energy can displace diesel fuel, which can reduce the subsidies required to support diesel. At the same time, diesel subsidies can be scaled back in order to allow renewable energy to become more competitive. In attempting such transitions, however, policymakers would need to carefully structure subsidy reforms so as not to put sudden or disproportionate burden on ratepayers. Savings from subsidy reform could be temporarily be redirected, for example, to defer the costs of energy for low-income households as a short-term and temporary “safety net.” If successful, strategies for using renewable energy to support subsidy reform in remote communities could ultimately serve as a model for such reform in non-remote areas as well.

Different remote areas will face different challenges with regard to financing and require different solutions. A key challenge for policymakers is how to deploy limited public resources most appropriately and efficiently to address barriers and leverage additional sources of capital. The next section discusses additional policies that can help achieve these objectives in remote areas.
5. LESSONS LEARNED: POLICY CHALLENGES AND POTENTIAL SOLUTIONS

The discussion contained in this section is drawn primarily from the lessons learned from the case studies and from consultations and interviews with remote area experts and policymakers. These recommendations do not reflect the full range of potential solutions; rather, they reflect initial priorities and a starting point for additional conversations about remote area energy policy development. This section includes a short list of policy and implementation challenges, and each challenge is accompanied by a set of possible solutions. These challenges are divided into several broad categories:

1. Scaling back fossil fuel subsidies;
2. Assisting with training and the lack of technical expertise;
3. Assisting with project planning and implementation;
4. Designing appropriate incentives;
5. Overcoming the issue of scale;
6. Increasing research and development (R&D) funding;
7. Prioritizing energy efficiency;
8. Determining the appropriate level of RE penetration;
9. Mitigating risk

5.1 SUBSIDIES

National governments may want to explore innovative subsidy reforms

Several of the IEA-RETD countries currently subsidize energy in remote areas. Subsidy reform can be a controversial topic since energy can constitute a significant share of remote communities’ annual expenditures and represent a significant share of individuals’ household budgets. Increases in energy prices can significantly impact economies and livelihoods, particularly in areas that face temperature extremes (e.g. remote areas with long winters). Subsidy reform is a vast and complex topic; as a result, it is beyond the scope of this report to treat it comprehensively. However, recognizing its importance, a detailed investigation into energy subsidies in remote areas and potential strategies for reform is recommended as a topic for further research. As an initial step, however, it is recommended that governments and utilities examine how subsidies could be shifted, and how upfront investments in renewable energy technologies in the near term could unlock energy savings in the long-term.

For instance, one approach could allow renewable energy investment costs and renewable energy savings to be shared in national-regional partnerships, or in avoided cost contracts with independent power producers. An example could be a community in which retail electricity prices are artificially maintained at the same levels that are paid in non-remote areas. In El Hierro, for example, renewable energy investments and savings could be shared between the national government and the community, with the costs of these subsidies recovered either from ratepayers in non-remote areas or through national government budgets (i.e. recovered from taxpayers).
energy generated direct subsidy savings for the government. In other words, the introduction of renewable resources into the system decreased the amount of diesel fuel required and therefore decreased the total subsidy needed to maintain prevailing rates. To support renewable energy, the government could pledge a portion of the avoided subsidies to renewable generators in the form of an incentive. The overall result would be that electricity rates in the remote community would remain at the same level, the government would save money on subsidies, and new renewable energy capacity would be installed. Although subsidies for conventional fuel come in many different forms, similar analyses could be performed across different subsidy types. Ultimately, it will be necessary to adopt a more holistic view of existing energy subsidies, and to examine each part individually as well as how it relates to the region’s overall energy strategy, and development objectives.

5.2. TRAINING
Training programs may be helpful to support energy systems in remote communities

As discussed in Section 3.1.4, a major barrier facing renewable energy deployment in remote areas is the availability of the technical expertise required to install and maintain renewable energy systems. Although some remote areas have an established local energy service industry, other remote areas are too small and isolated to attract and retain full-time equipment technicians. Moreover, the need to import expertise periodically can be inconvenient and prohibitively expensive. In response to this challenge, a number of different approaches could be adopted.

5.2.1 TECHNICAL ASSISTANCE NETWORKS
One solution is the establishment of technical assistance networks that can provide both training and on-call services to remote communities. Such networks can be designed to serve a range of different remote areas and can provide service after manufacturer and installer warranties have expired. The strengths of this approach are that expertise could be centralized and dispatched on an as-needed basis to different remote areas. The limitations are that it would not necessarily create capacity within remote communities to service equipment. Some companies effectively serve as a technical assistance network for local installers. It is common practice for Trama TechnoAmbiental (TTA), for example, to work in partnership with local installers who can then provide on-the-ground operations and maintenance services.

5.2.2 DIRECT TRAINING
Another natural solution to the lack of barrier would be to provide training to technicians in remote areas. A key question, however, is how best to structure and deliver the trainings. A few different approaches have been developed:

5.2.2.1 PRIVATE SECTOR LED
In some communities, manufacturers or project developers are able to supply limited training in system operations and maintenance, such as GE providing training on wind turbine maintenance in Kodiak.
Private sector trainings may not be a full solution, however, because the provision of training is not core to many manufacturers’ or developers’ business models.

5.2.2.2 NON-PROFIT LED

Non-profits are active in training technicians for remote areas, and particularly in the developing world. Practical Action in Peru, for example, has established a training center for remote areas RET technicians in Cajamarca, Peru as well as an online consultation system for remote technical assistance. Another approach used effectively in developing countries is to train a network of grassroots trainers that can then identify and build capacity among groups unlikely to emigrate. Such approaches have been successfully developed by organizations such as the Barefoot College.52 Remote technician training can be a key lesson transferred from developing to developed country remote areas.

5.2.2.3 GOVERNMENT LED

In many communities, the government can play an active role in assisting or leading training efforts, either independently or in collaboration with universities, colleges, and the private sector. For example, El Hierro supported an initiative to create a technical higher education program for renewable energy.53 The Ministry of Education, Universities, Culture and Sports of the Canary Islands Government signed an agreement with the renewable project owner Gorona del Viento S.A. (see El Hierro case study). The program is currently offered by the Instituto de Educación Superior Garoé (IES Garoé).54 It is expected that the program will attract people from other Canary Islands to El Hierro – previously students from El Hierro had to go to the bigger islands for more specialized education.

5.2.2.4 UTILITY LED

In Ramea Island NFLD, the utility has played an active role in assisting with training and technical assistance for on-site engineers. In remote areas where utilities are pursuing the development of renewable energy, they may play a significant role in supporting training as well. Similar utility-led programs and initiatives are found in Reunion Island, led by partially state-owned EDF.

5.2.2.5 ACADEMIC INSTITUTIONS

Specific partnerships with academic institutions and vocational schools can be established specifically to assist remote areas with project development and ongoing technical and operational support. Such partnerships, however, should focus on alternative delivery models. Traditional academic training, for example, may also not be a full solution since remote community members may have difficulty commuting to and participating in centralized programs. Training can be delivered through distance learning or hybrid online / onsite programs that combine distance courses with hands-on modules.

There are ways to combine elements of these different models in innovative ways. One option is to work with academic institutions to use remote areas as “living laboratories” for their students. This could involve, for example, embedding engineering or technical students in remote areas for extended periods.

---

52 See www.barefootcollege.org
53 The “Ciclo Formativo de Educación Superior,” http://www.20minutos.es/noticia/688883/0/
54 See http://www.iesgaroe.org/
of time to provide them with an opportunity to gain hands on skills, while providing remote communities with service. The University of Dundee in Scotland is currently working with Eigg as a “living laboratory” for its Masters students. An alternative approach would be to institute a program similar to remote doctor clinics in India: using wireless telecommunications to exchange photos and short videos, health issues in remote communities of India can be diagnosed at a distance, and prescriptions can be recommended digitally without requiring the physical presence of the doctor. Such an approach could likely work for the majority of routine troubleshooting issues encountered with renewable energy systems like solar and wind power.

5.3 PLANNING

National governments may allocate funds to support detailed energy planning and stakeholder engagement processes in remote areas.

As discussed in Section 3.2.7.1, the development and management of energy systems in remote areas requires a significant amount of planning – even where remote grids rely exclusively on diesel generators. Remote areas cannot count on neighboring communities (or countries) to help balance energy supply and demand. The integration of renewable energy into remote area grids can add additional layers of complexity to grid management and control. In order to support planning efforts, governments can provide grants to support facilitated planning processes that bring together the stakeholders that will be impacted by renewable energy integration, such as the utility staff (managers and engineers), regulators (if applicable), renewable energy developers and technical experts, local residents, community organizations, and government representatives. Such planning sessions would seek to determine which available renewable resources could be integrated into the grid, what additional system upgrades would be required, and in what sequence the integration should occur. Such planning processes could also seek to optimize the penetration levels of different resource types according to available resources and other policy objectives (e.g. achieving renewable energy goals). A similar process could occur for transportation systems, and to a lesser extent, for heating/cooling needs. Decision making tools such as the HOMER software, RETScreen, or other similar software systems can be employed to support such optimization. Such iterative and multi-stakeholder planning efforts replace processes in which renewable energy goals are set by government and then left to utilities to interpret and implement. These planning processes can be viewed as comparable to the integrated design processes that underpin the modern green building industry and which pull together relevant stakeholders at the outset of the design process rather consulting each serially as the project moves forward. Many governments provide grants to support green building design ‘charrettes’ and governments could make similar grants available to support comprehensive remote area renewable integration planning.

5.4 INCENTIVES AND FINANCING

Incentives function best when they are clear, stable, and designed to foster long-term, replicable solutions.
Incentives are currently deployed internationally in a wide range of different forms in order to achieve a variety of different policy objectives. While it is beyond the scope of this paper to provide a detailed overview of the literature on renewable energy policy design, this section broadly discusses some policy considerations that apply specifically to remote areas. These include:

**Market structure and feed-in tariffs.** Remote area market structure may dictate the types of incentives that can be deployed. Incentives in many IEA-RETD countries’ non-remote areas are structured to enable independent power producers to produce and sell energy. As can be seen in the case studies, however, energy systems in many remote areas are managed by single entities or monopoly utilities. As a result, incentives that are used in non-remote areas to encourage IPPs, such as traditional feed-in tariffs, may not be appropriate or relevant in remote areas. Instead, it may be necessary to provide grants or performance-based incentives directly to the utility or remote ESCO. Several models for “off-grid” feed-in tariffs have been proposed and off-grid feed-in tariffs have been developed in developing countries such as Ecuador, Peru, and Tanzania, as well as in the overseas departments of France such as Reunion Island and Guadeloupe. Text Box 4 provides a short overview of feed-in tariffs in remote areas and discusses off-grid feed-in tariffs in greater detail.

**Text Box 4. Feed-in tariffs in remote areas.**

Feed-in tariffs (FiTs) are one of the most prevalent policies to support renewable electricity globally. Currently, over fifty countries have some form of FIT in place. FITs have historically been considered a policy to support systems that are connected to centralized electricity grids. The term “feed-in” derives from the fact that the policies were initially developed to enable independent power producers to feed their electricity into the national grids of countries such as Germany and Denmark. Since they were first enacted in the 1980s and 1990s, FITs have diffused widely around the world and evolved into many different designs (Couture et al., 2010). Today, the unifying feature of FITs is that they typically provide generators with performance-based cash payments ($/kWh) that are determined administratively (rather than through market competition) and available on a standard offer basis. FITs may also include policy elements such as interconnection protocols, purchase and dispatch requirements, and contracting rules (Rickerson et al., 2011).
5.4.1 INCENTIVE DESIGN

To the extent that there are IPPs present in remote areas (e.g. in larger remote areas), incentives will function best if they are a) performance based, b) tied to remote monitoring systems and c) matched to renewable energy system life in order to ensure that owners continue to maintain and operate the systems for the duration of the project. Incentives will also be more successful at attracting investment to remote areas if they are available on a standard offer basis in order to allow smaller scale systems to be installed in a streamlined fashion. Standard offers are also effective at allowing a broader range of capital providers to compete for project locations and participate in renewable energy investment. Moreover, in many remote areas, it may be possible to adopt earlier feed-in tariff designs, such as those based on avoided costs such as the US Public Utilities Regulatory Policies Act (PURPA), or a fixed percentage of avoided retail costs as in Germany’s Stromeinspeisungsgesetz, which was in place from 1991 to 2000. Due to the high costs of diesel supply in remote areas, an avoided cost-based structure

Text Box 4. Feed-in tariffs in remote areas. (Continued)

FITs have been successful at driving renewable energy market growth and have supported the majority of the world’s wind and PV resources. As a result of their success, there has been increasing interest in adapting feed-in tariffs to off-grid or remote areas (Moner-Girona, 2009; Moner-Girona, 2008; Solano-Peralta, 2008; Solano-Peralta et al., 2009). Several developing countries have helped pioneer FITs for remote areas and off-grid applications. These include:

- **Ecuador.** Ecuador offers a 12-year FIT to wind, PV, biomass, geothermal, concentrating solar power, and small hydro systems. Ecuador differentiates its FITs according to whether the systems are located on the mainland or whether they are located on the Galápagos Islands. Wind, for example, gets $0.0913/kWh on the mainland and $0.104/kWh on the islands (Rickerson et al., 2010a).

- **Peru.** Peru uses an auction to support main grid renewable energy systems. In parallel, however, Peru implemented a FIT for off-grid renewable energy systems in August 2010 in order to expand rural electrification. The FIT rates range from between $0.09 - $0.33/kWh, depending on region, system size, and ownership (i.e. public or private investment).

- **Tanzania.** Tanzania’s Small Power Producer (SPP) program allows generators to connect to either centralized grids or to mini-grids. The SPP regulations enable development of renewable and cogenerated electricity through standardized power purchase contracts, standardized feed-in tariff (FIT) payments, and streamlined interconnection and licensing requirements. Generators connected to the mini-grids receive a payment based on the avoided cost of diesel generation in the mini-grids for 15 years (Rickerson et al., 2010b). In 2011, that rate was USD $0.243/kWh.

In addition to these developing countries, several countries in Europe have established FITs for their island territories. These include France, which pays higher rates to generators located in its overseas departments, Greece, which has different rates for systems located on its islands, and the UK, which has established a policy for off-grid rates.
may provide sufficiently high prices to enable cost-recovery in many areas; also, if designed on a “share the savings” basis as in Ramea in Canada, it can also provide utilities with valuable cost savings over existing diesel supply.

5.4.2 ADDITIONAL SUPPORT
Remote areas require support for more than generation. While many incentives support renewable energy production, they do not necessarily support the controls, storage, remote monitoring systems, and other infrastructural components that are critical requirements project success. Incentives for control, storage, and remote monitoring technologies, or for the technicians that provide such services, may be explicitly considered, especially since mechanisms such as ancillary services and capacity markets typically do not exist to support storage or load control in remote areas and would be impractical to create. When designing policy for remote areas in the near-term, it may also be necessary to include subsidies for advanced diesel gensets that can replace aging systems and still provide system reliability in high penetration systems. Subsidies can also be provided to substitute biofuels in the generators where applicable. Floreana and Bonaire, for example, are both exploring biofuels for electricity generation.

5.4.3 TAX BENEFITS
Although tax incentives are used around the world, special consideration may need to be given to how these can be implemented in remote areas. First, depending on the remote area size, tax credits may be difficult to utilize because there might not be sufficient tax equity available to invest and the deals are likely too small to attract outside tax partners. Second, relief from import duties may reduce the costs of importing equipment from neighboring countries that may be closer geographically than a country’s non-remote areas. However, tax exemptions on smaller aspects of remote energy systems such as inverters, remote monitoring equipment, solar panels, wiring, efficient appliances, insulation, building materials, or other components may be considered. An interesting example of this is found in the Philippines, which has included a full spectrum of tax incentives, value-added tax (VAT) exemptions on both RE system components and electricity sales, duty exemptions on imports, accelerated depreciation, as well as tax credits on domestic capital equipment purchases to lower the barriers to RE investment throughout the country.

5.4.4 INNOVATIVE TARIFF STRUCTURES
RE systems in remote areas may not need incentives if they can be built and operated for less than a utility’s existing costs. In Ramea, for example, privately-owned wind turbines are paid a portion of the difference between the utility cost of generation and that of the turbines themselves using a “share the savings” approach. This incentive creates a revenue stream for the generator, but it is not an incentive in the traditional sense because the utility is generating savings for itself. The developer remains responsible for the operations and maintenance of the site, and is only paid for electricity generated and exported to the grid. This is akin to the avoided cost-based approach described above, and used in earlier feed-in tariffs around the world.
5.4.5 SYSTEM PLANNING
Incentives need to be linked closely to system planning. Incentive programs in some non-remote are accompanied by policies that require new generation to be accommodated. These include requirements that utilities guarantee interconnection, ensure that grids are strengthened, and guarantee power purchase in order to accommodate renewable generators. While such requirements may be useful to achieving renewable energy transition in non-remote areas, they would create significant challenges if implemented in remote areas where the systems need to be more carefully planned and balanced.

5.5 SCALE
National governments can support and facilitate aggregation programs
Aggregation refers to bundling smaller units in order to achieve the advantages of scale. In the context of remote area energy systems, aggregation can be used to accomplish a range of goals.

5.5.1 ACCESS TO TECHNOLOGY
Remote areas may not be able to access the technologies required to achieve higher penetrations of renewable energy because of the inability (or unwillingness) of manufacturers to supply product. During periods of high demand for wind energy, for example, smaller-scale projects were unable to secure “name brand” wind turbines because their orders were not of sufficient size (Bolinger, 2011). Remote areas face similar challenges, often compounded by geographic isolation. Remote areas may also be unable to secure technologies such as energy efficient appliances because of a lack of existing distribution and sales channels. **Aggregation of demand for renewable energy and energy efficiency technologies within a remote community or across several remote communities could create sufficient demand to attract manufacturer and distributor attention.** Inability to access new technology may also result in remote areas choosing refurbished technologies such as wind turbines, which may be cheaper but often involve higher operations and maintenance requirements.

5.5.2 ACCESS TO LOWER COST SYSTEMS
A second benefit of aggregated purchasing is the ability to unlock economies of scale and drive down the cost of clean energy systems through bulk purchases. This is an increasingly common practice, such as in several cities in the US where group purchases of PV systems by aggregations of residential buyers has resulted in lower installed costs. Bulk procurement was used, for example, to buy solar home systems in Miyakojima. A similar approach could be used in remote regions, or in collections of remote islands, such as the Comoros, or the Philippines.

5.5.3 ACCESS TO FINANCING
As discussed in Section 3.3.4.2, remote communities may not be able to secure capital to finance renewable energy systems from commercial lenders because of the scale of their purchases. In order to increase the pool of potential capital providers and create competition to reduce lending rates, demand for financing could again be aggregated within or across remote communities.
5.5.4 ACCESS TO ALTERNATIVE OWNERSHIP STRUCTURES

As discussed in Section 3.3.5, many of the innovative ownership models for clean energy deployment may not be development at the scales contemplated in remote communities. According to the IEA-RETD BizZ project, for example, energy performance contracts may be available for projects as low as $100,000 but are often an order of magnitude higher (Würtzberger et al., 2011). By aggregating demand, communities can gain access to new ownership models and under more attractive terms. Although not a remote areas, the City of New Bedford in the US State of Massachusetts recently aggregated all of its municipal property in order to enter into an energy supply contract with a PV provider. The PV provider was able to identify up to 10 MW of attractive development sites and submit a bid to develop projects well below the city’s current utility rates.

Although aggregation is an attractive option, the costs of organizing such an effort, including marketing the program and processing applicants, can be high. The most effective aggregating agents are likely to be the community’s utility and/or the citizens of the remote communities themselves. However, additional support and funding from government may be required to support the aggregation process and to provide technical assistance to support the procurement. This could include providing expertise to validate and select technologies to be procured (for example, high efficiency appliances) and to negotiate the terms of the contract that the community signs with the technology provider, bank, ESCO, or other entity.

5.6 RESEARCH AND DEVELOPMENT

Renewable energy in remote areas can be supported through research and development programs that are beneficial for both IEA-RETD and non-IEA-RETD countries

Remote areas are often not a policy focus for developed nations that enjoy close to 100% electrification rates because they tend to represent both a small segment of the overall population and are concentrated in comparatively small areas of the countries’ overall land mass. Even if renewable energy resources are competitive in remote areas, it may still be difficult for policymakers to focus on strategies to achieve their implementation because of a lack of administrative resources. When faced with the choice of devoting resources to policy development affecting millions and policy affecting only a few communities, many policymakers may feel the need to prioritize the former.

A narrow focus on the direct beneficiaries of a given policy, however, obscures the fact that non-remote areas can derive important benefits from successful renewable energy deployment in remote areas. Remote areas are in many cases a microcosm of non-remote areas. The renewable energy integration challenges faced today by remote areas will be mirrored on a much larger scale in non-remote areas as national governments pursue aggressive renewable energy targets (e.g. such as Germany’s goal to achieve 80% of national electricity from renewable sources by 2050). Remote areas can be a comparatively low-cost and contained proving ground for achieving high penetrations of renewable energy. As such, governments could direct not only policy attention to remote areas, but also research, development and demonstration funding. This could create a paradigm shift in the manner in which
energy projects in remote areas are perceived, prioritized, and funded. El Hierro, Miyakojima, Reunion and Ramea are examples of remote areas that have received national R&D funds to demonstrate new energy innovations.

5.7 EFFICIENCY

Policies to encourage the adoption of efficient technologies and to foster more efficient energy use can help reduce the scale of supply and infrastructure needs, and save individuals, businesses, as well as government money.

It is widely acknowledged in the electricity sector that inefficient appliances contribute disproportionately to peaks in electricity supply, which can compromise system reliability and dramatically increase the total cost of supply. Similarly, inefficient trucks and vehicles contribute to an inflated need for storage facilities, while inefficient furnaces, boilers and air conditioners can consume over twice the energy that more efficient models require. In each of these instances, technological choices contribute to an excessive use of non-renewable resources, and incur additional costs for governments, industry, businesses, and consumers. Due to the higher cost of energy and fuels in remote areas, the continued use and deployment of inefficient technologies in these areas is increasingly unsustainable. A number of different approaches could be adopted to resolve this problem.

First, establishing substantially higher efficiency standards on the products, vehicles, and appliances imported into and sold in remote areas could significantly reduce overall community energy needs, and in some cases even reverse load growth over the medium-to-long term, all else being equal. For government and other bodies, procurement standards could help ensure that only “front-runner” technologies are adopted and deployed in remote regions.

Second, ESCO models could focus on energy efficiency by providing innovative, low-cost or on-bill financing mechanisms to enable homes in remote areas adopt more efficient, big-ticket items like furnaces. They could also be used to improve lighting systems, insulation, and other aspects that contribute to excessive energy consumption.

Another approach that could be used is known as a “feebate”: a fee is levied on the less efficient models in each product class, while a corresponding rebate is offered to the most efficient models. The fees therefore pay for the rebates. This policy can help narrow or eliminate the price spread between efficient and inefficient models, and helps individuals make decisions that are better for them, as well as for society. A similar approach could be used for vehicles, including quads, snowmobiles, motorcycles and the like.

As pointed out above, smaller overall energy requirements can help reduce the need for excessive infrastructure investments such as storage facilities and electric grids. A targeted focus on energy efficiency can therefore make it easier for remote areas to achieve high levels of renewable energy penetration, while saving substantial amounts of money in both wasteful capital investments, and superfluous energy consumption.
5.8 LEVEL OF RENEWABLE PENETRATION

It is currently cost-effective to include renewables in most remote area energy supplies.

For remote areas the time has arrived for the discussion of renewables to transition from “Is it cost-effective to install renewables?” to “How much renewable energy capacity is appropriate on my grid?” Remote areas overwhelmingly generate electricity from gensets powered by expensive and price-volatile diesel, Due to this, renewables typically provide a less-expensive option to supplement and replace a portion of this remote generation.

Typically, low-penetration renewable energy (up to about 20-30% on an annual energy production basis) can currently be cost-effectively included as part of a reliable, remote energy supply in most remote areas without additional incentives. This is in contrast to mainland grid supplies that may require consideration of externalities (e.g. a price on carbon) and broader environmental and social concerns to justify the inclusion of renewables.

Higher-penetration renewables, in certain remote areas, may be cost-effective. There may also be broader environmental and social considerations that make high-penetration renewables a good option for remote areas. In the longer-term, it is likely that higher-levels of renewable penetration will become more cost-effective – particularly if fossil fuel prices continue to increase, renewable technology costs continue to decline, and balance of system technologies (particularly storage) continue to improve.

5.9 RISK

How can governments help reduce the key risks that RE projects in remote areas face?

Remote areas may have difficulties attracting capital to invest in their energy or electricity infrastructure. They also tend to face a more diverse set of risks than projects in mainland areas and feature a more limited pool of potential capital providers. Among the many consequences of these factors is that the cost of capital will tend to be higher, as seen in Section 4.2.

There are many ways that governments can help reduce the wide array of risks than can influence remote area projects, including construction risks, revenue risks, operational risks, as well as financing, currency and political risks. Options range from establishing stable and enforceable contracts for electricity purchases, implementing clear, long-term policies and objectives, and providing institutional supports in the form of technical and operational assistance. Support can also consist in providing direct technical or training assistance to address non-economic barriers to renewable energy deployment, such as the lack of local expertise.

Risks can also be mitigated by the provision of supportive infrastructure, such as electricity distribution infrastructure, storage systems, ports, roads, or buildings. In particular, the availability of local engineers or technical staff, either from the local utility or from municipal staff can help provide on-site assistance, and reduce the length of delays when projects go off-line due to weather or other events. Also, governments may be able to provide targeted supports in the form of so-called ‘de-risking’ mechanisms.
such as credit or loan guarantees and insurance mechanisms, among others. These can contribute significantly to reducing the costs of financing, which in turn can play a significant role in lowering the costs of RETs, thereby increasing their competitiveness and attractiveness vis-à-vis other energy supply options.
6. CONCLUSION

As this report has shown, there is tremendous potential to develop renewable energy projects in remote areas. The economic case to begin transitioning away from fossil-powered systems toward a greater reliance on locally available renewable resources is growing stronger every year as fossil fuel prices trend upward, and renewable energy prices continue to decline. Furthermore, the environmental, economic and energy security risks already present in many remote areas demonstrate why kick-starting this transition is so timely, and important. While remote areas have unique challenges, and are exposed to a number of risks that are not typically found in central or mainland areas, the case studies included in Appendix A provide valuable insights into how some of these challenges can be overcome.

One of the many insights that flow from this analysis is that cooperation between government, communities, businesses, utilities, and the private sector is vital to the success and sustainability of remote area projects. While grid integration and energy storage in remote areas present technical and economic challenges, the management systems required to balance supply and demand in micro-grids are improving at a rapid pace, making the integration of a growing share of renewable electricity possible. Thermal energy needs can also tap into renewable energy sources, drawing on ground, air, or water-source heat pumps or locally available solar and biomass energy to serve local needs. In addition, new developments in vehicle technology such as electric vehicles make it conceivable that some remote areas could eliminate the majority of their dependence on transportation fuels in the years ahead. Throughout each sector, a more aggressive and targeted focus on energy efficiency in all areas of energy use is essential; improved efficiency can help scale down total energy needs, and provide a number of benefits and savings for governments, utilities, businesses, and individual citizens.

A further essential factor is developing the appropriate institutional and political environment required to foster greater renewable energy development in remote areas. A number of economic and non-economic barriers as well as a host of market failures continue to hinder deployment in many regions, in both developed and developing economies. For instance, remote areas can provide a valuable case study of how to undertake the important task of subsidy reform, by shifting government contributions away from increasingly costly subsidies toward more durable solutions.

Moreover, it is important to carefully bear in mind the importance of context, which includes but is not limited to the climatic, political, economic, educational and cultural dimensions, as well as the local communities’ needs and the available resource potential. Indeed, it is likely impossible to develop truly appropriate and sustainable solutions without tailoring them to local contexts. It is also important to set realistic objectives, and build on a sound foundation of community support.

Finally, as remote areas begin to increase their use of renewable energy technologies in the electric, heating, and transportation sectors, there is little doubt that they will begin to uncover a number of lessons, insights and technical innovations that can help and enhance renewable energy development and integration in non-remote areas. Indeed, remote regions can act as a powerful proving ground for innovative technologies, and can serve as a compelling demonstration that a fully operational renewable energy future is not only possible, but within reach.
6.1 ADDITIONAL RESEARCH

There are several areas that are beyond the scope of this report, but where further research and analysis is needed. The list below includes some of the areas where further work and analysis would be particularly valuable:

- **Research and analysis on high penetration RE scenarios**: As interest grows in remote areas, there will be a growing need for a deeper understanding of the technical, technological, behavioral, as well as institutional conditions required to move toward ever-higher penetrations of renewable energy. The comparative economics of low, medium, and high levels of RE penetration will need to be clearly evaluated and understood by policymakers. This includes a better understanding by all stakeholders (utilities, communities, politicians, individual citizens, etc.) of the complex trade-offs inherent in different energy paths. This analysis would lay out a technical and conceptual roadmap to different levels of RE penetration, in different contexts, and climates – its primary objective would be to make the different energy options more concrete, both from a conceptual and an economic standpoint.

- **Techno-economic analysis of the cost and technical impacts of introducing RETs**: The cost for supplying energy in remote areas can be misleading if not properly contextualized – this is particularly true for renewables. Several considerations affect the economics of renewable energy technologies (RETs). These include, but are not limited to rural electrification subsidies, limited access to technical expertise, logistical issues, small scales, storage issues, financing costs, and the prevailing level of poverty. Using HOMER Software, this analysis could compare the cost of a diesel-only system to that of a hybrid system for different scenarios, such as those outlined in the case studies. The analysis would illustrate the full, unsubsidized cost of remote power from a variety of sources, including diesel gensets and renewable energy technologies. This will also describe the impact of the differences in capital and operating costs between renewables and diesel.

- **Off-grid FITs**: As highlighted in Text Box 4, FITs have been used in off-grid applications in countries such as in Peru, in Tanzania, as well as in Reunion Island, and in many Greek islands. However, little research has been conducted on the unique technical and policy design considerations applicable to remote areas. For instance, an open-ended standard offer is unlikely to be workable in microgrid settings – this means that FITs may need further layers, such as detailed planning and siting requirements, location-specific program caps, unique interconnection and curtailment provisions, as well as a greater focus on complementary initiatives, such as demand response, smart meters, and storage.

- **Characterization of an “average” citizen’s energy demand in different remote areas, with an analysis of the cost-of-service, under different energy supply configurations**: This analysis would seek to create a benchmark for the “average” energy consumer in the six different remote area categories laid out in this report. By making a number of assumptions regarding the daily
energy needs of an average citizen in different climatic and geographical areas, this analysis would derive a benchmark for average, per capita energy demand in each of the regions. The analysis would then break down the energy use into the three major categories (thermal, transportation, and electricity), and provide the approximate cost of energy service for the average citizen in these areas under different configurations. For instance, it would be possible to evaluate a 100% diesel powered scenario (thermal, electric, and transport), a scenario where electricity is 80% renewable, thermal energy is 50% renewable, and transportation is 20% renewable, and so forth. In this way, it would be possible to derive approximate “cost per capita” metrics (in $/citizen) for energy service in remote areas under a variety of energy supply configurations.

- **Demand management in remote areas**: Developing enhanced demand management solutions for remote areas and microgrids is an essential component of achieving high penetrations of renewable energy supply in these areas. Demand response, energy efficiency, smart meters, and other inter-operable appliances and smart grid applications are beginning to be rolled out in some remote regions, such as in Reunion Island. Further research and case studies on the emerging technological solutions and customer engagement programs being deployed in both remote and non-remote areas could be valuable to provide concrete examples of how load management challenges are being addressed in different areas.

- **Financing models for remote communities**: Financing is one of the greatest challenges facing many remote areas seeking to upgrade or modernize their energy infrastructure. In some cases, such as in Samsø (DK), citizens have been directly involved in project financing, via the issuance of shares. However, this will not be possible in all cases, such as in developing countries. While much has been written on financing renewable energy projects (e.g. IEA-RETD’s RE-BIZZ initiative, de Jager and Rathmann 2008, etc.), little analysis has been conducted of the unique conditions required for successful financing in remote or off-grid areas. Drawing on new or alternative sources of financing can help reduce reliance on government sources of financing, and help increase local ownership and participation in energy projects.

- **Institutional and governance structure impacts on RET deployment in remote areas**: Examining the institutional and political structures can provide important insights into how certain jurisdictions, such as France, Spain or Denmark, have been successful at encouraging renewable energy development in remote or island settings. Institutional structures are particularly important in ensuring the long-term sustainability of remote area projects; this could help create a set of best practices, or a compendium of institutional or governance structures that could improve the success and sustainability of remote area energy initiatives.

- **Subsidy reform, or Scaling Back Fossil Fuel Subsidies**: Most, if not virtually all, remote areas benefit from some degree of subsidization of their energy services. This can range from subsidies for infrastructure, storage facilities and fuel deliveries to the direct subsidization of fuel prices. As a result, many remote areas depend vitally on energy services, and many are vulnerable to...
rising energy prices. While a number of jurisdictions have begun the process of subsidy reform (ramping down subsidies to fossil fuels while re-allocating them to emerging technologies and renewables), the issue remains politically sensitive in many areas of the world. Examining the various pathways to achieve successful energy subsidy reform could therefore be a further avenue worth exploring, one that could complement some of the existing literature on energy subsidies, and provide a useful guide to the key issues.

- **Innovative approaches to fostering cooperation between different groups and stakeholders in remote areas**: One of the challenges in many remote areas is that residents can, in some cases, be prone to looking after themselves, which can make community-level cooperation difficult. This research would provide an overview of some of the innovative ways in which community-based and cooperative models of energy development have been used around the world to address these challenges, either at a community-level or in collaboration with local utilities.

- **Innovative storage options**: It is almost universally acknowledged that advanced storage solutions will be required to achieve high RE penetrations. This analysis would provide a detailed evaluation of the various trade-offs of different storage solutions, including cost, reliability, size or scale, and site-specificity. While the storage market is evolving rapidly, this would provide an up-to-date evaluation of different storage options.
KODIAK, ALASKA, USA

REGION BACKGROUND:
Kodiak is the second largest island in the USA and is located about 400km southwest of Anchorage, Alaska. Prior to the project, the island received 80% of their power from a two-unit hydroelectric plant and the remaining 20% from seven diesel gensets. In 2007, the Kodiak Electric Association (KEA) set a goal to achieve 95% renewable power by 2020. The Pillar Mountain project is the first step towards achieving this goal.

ACCESS:
Kodiak is an island, so access from the mainland is either by boat or airplane. The project installation had special challenges. The gravel road that leads up to the wind farm site was inadequate and had to be upgraded before the farm could be completed. The ports typically do not freeze over, although there are frequent clouds and fog.

CLIMATE:
Kodiak is in the subpolar oceanic climate zone. It has long and cold winters with mild summers. There is heavy precipitation thought the year, although rainfall decreases in summer. During summer, the temperature ranges from 4°C to 20°C, and in mid-winter the temperatures average -4°C.

MAIN REGIONAL ECONOMIC ACTIVITIES:
Fishing and tourism are the major economic activities. The island has a timber industry, and uses its status as a regional hub to provide governmental services to the surrounding areas.

TYPES OF ENERGY NEEDS BY SECTOR:
The fishing industry has seasonal energy needs that match up closely to the increases in demand due to tourism. The heating needs, however, increase in the winter.

PROJECT DESCRIPTION:
This Pillar Mountain Wind Project installation started in 2008 and was completed in summer of 2009. Three utility scale wind turbines were installed to make the Kodiak grid a low-penetration renewable system. It is part of a broader plan to transition Kodiak to a high-penetration renewable system.

PROJECT OWNERSHIP:
The Kodiak Electric Association (KEA) owns, operates, distributes, and retails the electricity grid on Kodiak Island. The KEA is a not-for-profit electric utility that is owned by its members (i.e. cooperative).

INSTITUTIONAL FRAMEWORK/SUPPORT:
The KEA is a member-owned co-operative utility governed by a 9 person elected board. KEA has approximately 4,000 members.
PROJECT INSTALLER:
KEA installed the project with support from the wind turbine manufacturer, GE. Local contractors were used when possible, for example for pouring concrete.

LOAD DEMAND AND GROWTH:
KEA’s grid varies from 11 to 25-MW peak load. The system has capacity for additional load growth, although without additional renewable resources the electricity will need to be generated from diesel.

GRID GENERATION SOURCES:
The system is composed of 3 x 1.5 MW GE SLE turbines on 80-m towers integrated with an existing 2 x 10MW hydro turbines at Terror Lake, 1 x 7MW combined cycle diesel generator and an additional 26MW of reciprocating diesel generator capacity. The integration equipment included capacitor banks to reduce wind power fluctuation and digital governors at Terror Lake to improve the hydro ramp rates. In 2010, wind provided 7.7% of the island’s electricity, hydro provided 85.2%, and diesel 7.1%. KEA estimates that the costs for generation are US$0.12/kWh (€.09 /kWh) for wind, US$0.068/kWh (€.052 /kWh) for hydro, and $0.2538/kWh (€.1938 /kWh) for diesel.

TARIFF STRUCTURE:
The tariff is roughly US$0.20/kWh (€0.15/kWh), although the exact rate varies between residential and commercial users, and there are special rates for processing plants. Large power uses have a tariff that includes demand charges. The tariff fluctuates based on how much of the electricity must be produced from diesel.

PROJECT FINANCING:
Total cost was about US$21.4 million (€16 million), US$4 million (€3 million) of which came from Alaska’s Renewable Energy Grant Fund.

PROJECT O&M:
In 2010, the wind turbines reduced diesel consumption by roughly 3.4 million liters, which is estimated to have saved the utility roughly US$2.3 million (€1.7 million) in fuel costs during its first year of operation. GE also signed a two-year service agreement with KEA. Under this agreement, GE will perform routine maintenance of the wind turbines for two years while training KEA crews in maintenance practices.

CURRENT STATUS OF PROJECT:
Based on the success of the first phase of the project, KEA is planning to continue into further phases. By August 2012, KEA intends to install an additional 3 x 1.5MW GE turbines. A pumped hydro storage project at Terror Lake and transmission upgrades will soon follow. Together these investments are expected to provide 98% of the island’s electricity from renewable sources.
Figure 11: Pillar Mountain Wind Farm. Source: Dake Schmidt, http://www.dakeschmidtphotography.com/
## Lessons Learned

**Technical**

For mid-size systems, a renewable transition plan should begin with low-penetration before proceeding to a high-penetration system. KEA developed a long-term plan for increasing the use of renewables on the grid and reducing the reliance on expensive imported diesel fuel. The success of the initial low-penetration system encouraged the utility to increase the transition to a high-penetration renewable system. They now expect to beat their original renewable energy target, achieving 98% of their electricity from renewable sources.

**Social-Economic**

Using renewables to offset diesel production can reduce electricity rates and provide long-term electricity price stability. On Kodiak, the wind electricity is estimated to cost US$0.12/kWh (€0.08/kWh) while the diesel power cost estimate is US$0.2538/kWh (€0.19/kWh) and rising.

**Institutional**

Including a training period in the first years of a project's operation can build capacity in the local utility. GE was contracted to provide the first 2 years of maintenance while training the KEA staff. This strategy enables the local operators to learn from the foreign experts.

**Financial**

Government subsidies may be necessary to help smaller utilities deal with the large upfront capital costs inherent in most renewable energy projects. The state of Alaska’s Renewable Energy Grant provided capital to enable the project.

**Environmental**

Winter weather conditions limited access to the project. The project had to be planned around a specific window when the weather was appropriate for installation.

---

RAMEA ISLAND, NFLD, CANADA

REMOTE AREAS WITH LONG WINTERS

RAMEA ISLAND PROJECT | WIND/DIESEL/HYDROGEN HYBRID | POPULATION OF 631

REGION BACKGROUND:
Ramea is a small remote island located off the southern coast of Newfoundland in Canada. It has a population of approximately 631 inhabitants, with 354 electricity customers. The island was once an important outpost during the days of the cod fishery, but when the industry collapsed in 1992, the population declined significantly.

ACCESS:
The only access to Ramea is either by private boat, or by ferry from the mainland. This made it difficult for cranes in particular to access the project site in order to install the wind turbines.

CLIMATE:
Ramea is in the Atlantic Climate Region at approximately 55 degrees of latitude. It has relatively long winters and comparatively short summers due to its northern location. There is steady average precipitation thought the year (~100-150mm/month), although rainfall decreases somewhat in summer. During summer, the temperature averages 15°C, while averages in the winter months of January and February are around -4°C. The temperatures on Ramea remain moderate compared to the mainland due to the presence of the Gulf of St. Lawrence.

MAIN REGIONAL ECONOMIC ACTIVITIES:
Fishing and tourism are currently the primary industries on Ramea. While the fisheries have declined significantly since the collapse of the cod fishery in the early 1990s, fish processing facilities remain active on the island on a seasonal basis.

TYPES OF ENERGY NEEDS BY SECTOR:
Newfoundland Hydro has 354 electricity customers on Ramea, including a few small businesses and industries. The fishing industry on Ramea undergoes some seasonal variability, as does the tourism industry, which has been growing in recent years. Peak electricity demand is currently 1,078kW, and is reached during the winter months. In terms of total generation, Ramea generates approximately 4,200 MWh of electricity per year, the majority (>75%) of which comes from on-site diesel generation.

PROJECT DESCRIPTION:
The first phase of the Ramea project began in 2004 with the installation of the six (6) 65kW wind turbines by Frontier Power Systems. In 2009-10, the second phase of the project began with the installation of three (3) 100kW turbines. And finally, in early 2012 the third and final phase of the project was completed with the installation of a hydrogen system (250kW), making the system a fully integrated wind-diesel-hydrogen (WDH) hybrid.
PROJECT DESCRIPTION CONTINUED:

Hydrogen is produced from the electrolysis of water when wind power generation exceeds the island’s total electricity demand. The electricity is then stored in on-site storage facilities. The hydrogen system helps avoid dumping of wind generated electricity during the windiest days, or when load is low, as on summer evenings. The community is then able to draw down on the stored hydrogen energy as needed. The goal of the project is to test the feasibility of wind-diesel-hydrogen technologies in northern and remote communities and provide lessons for future projects. A longer-term goal is to demonstrate the feasibility of supplying upwards of 90% of Ramea’s electricity needs with renewable energy.

The project involved the support of Nalcor, the federal and provincial governments, the Atlantic Canadian Opportunities Agency (ACOA), Frontier Power Systems and the collaboration of the Wind Energy Institute of Canada (WEICan).

PROJECT OWNERSHIP:

The project ownership of the Ramea wind-diesel-hydrogen system is shared. Frontier Power Systems owns the six (6) initial 65kW turbines that comprise the first phase of the project, and is responsible for the O&M costs of maintaining them. Penney Industrial installed the hydrogen system in 2009, although the hydrogen project itself belongs to Nalcor and its subsidiary, Newfoundland Hydro. Nalcor financed and built many other components of the project, including mechanical work, piping, exhaust fans and the like. Nalcor has also developed an Energy Management System (EMS) that will provide automatic control and monitoring of all components of the WDH system. Nalcor Energy will retain all property rights related to the EMS and the hydrogen system, while Frontier Power Systems remains responsible for the first phase of the project.

INSTITUTIONAL FRAMEWORK / SUPPORT:

Nalcor is the primary company in control of the Energy Management System (EMS) on Ramea, though Frontier Power Systems remains responsible for the operation of its six turbine units that represent phase 1 of the project. In return for selling power to the grid, FPS receives a tariff based on the avoided fuel cost, which is linked to the fluctuating cost of diesel. Nalcor has a policy of “sharing the savings”, which means that the system operated by FPS benefits from the upward trend of fossil fuel prices.

Also, Frontier Power Systems continues to provide operational and troubleshooting services for the wind component of the system as needed, while Nalcor provides on-site staff that now take care of both the hydrogen system as well as the existing diesel supply and maintenance needs. In addition, Nalcor aims to provide first-responder training to the local fire department on the island. This will provide additional on-site capacity. One of the reasons a hydrogen combustion engine was selected is that it would prove easier for existing staff and engineers to understand and work with the new technology.

PROJECT INSTALLER

Frontier Power Systems installed the Ramea wind-diesel hybrid system in collaboration with the Wind Energy Institute of Canada (WEICan). Penney Industrial helped install the hydrogen system in collaboration with Nalcor engineers. Hydrogen Engine Corporation provided the hydrogen system.
LOAD DEMAND AND GROWTH:
With a population of 631, Ramea’s annual load is approximately 4,500 MWh. Load growth has been almost negligible, and has declined significantly since the collapse of the fishery. This means that Ramea has more generation capacity than it needs to supply current levels of electricity demand. The excess diesel capacity provides the base load generation, as Nalcor engineers aim to maintain a minimum 30% capacity factor on their diesel generators.

GRID GENERATION SOURCES:
The current electricity system in Ramea is composed of the following generation assets:

- three (3) x 925kW diesel generating systems,
- six (6) x 65kW wind turbines
- three (3) x 100kW wind turbines
- one (1) x 250kW hydrogen generator.

In 2008, the six wind turbines produced approximately 1,000 MWh/yr and avoided 700 tonnes of carbon emissions per year. With the addition of three turbine units in the fall of 2009, annual regeneration now exceeds 1500kWh. During periods of low electricity demand, the wind system combined with hydrogen is able, in theory, to completely displace the diesel resources, and provide all of the islands needs. On an annual basis, approximately 1/3 of total generation is supplied from renewable energy technologies.

PROJECT FINANCING
The anticipated cost for the first phase of the Ramea project was $1.17 million CAD (€0.89 million). The project was 20% over budget, leading to total final cost of $1.4 million. This means that the total installed cost for the first phase was $3589/kW (€2733/ kW). The federal government provided support of $474,550 through its Technology and Early Action Measures (TEAM) program administered by NRCAN, $245,000 of which will be repaid in royalties over the course of the project’s life. The federal government also provided $112,250 in in-kind contributions. For the second phase of the Ramea project, the Atlantic Canadian Opportunities Agency (ACOA) contributed $3 Million (CAD), the provincial government contributed a further $4.5 Million, while an additional $2.5 Million was provided by Nalcor. This funding includes money for the R&D components of the project.

For the first phase of the project, Nalcor offered FPS a purchase agreement for electricity supplied to the grid based on the avoided fuel cost of diesel on the island. This is based on a “share the savings” formula that provides FPS a portion of the upside of rising diesel prices, while still offering the utility cost savings over its existing diesel generation.

PROJECT O&M:
After Phase 1, the six initial wind turbines reduced diesel consumption by roughly 100,000 liters, which represented approximately 10% of total annual fuel consumption. Frontier Power Systems remains responsible for the operation and maintenance of the first phase of the project, while Nalcor is responsible for the second phase. With the second phase now complete, it is expected that total avoided fuel consumption will decrease by 25%, reducing approximately 250,000 liters of diesel consumption per year.
CURRENT STATUS OF PROJECT:
Based on the success of two phases of the project, Nalcor is currently evaluating the ongoing project success, and is learning valuable lessons about micro-grid management on remote islands. One of the primary objectives of the project was to gather data and learn lessons about renewable energy system management in remote regions. While grid integration as well as voltage and frequency stability have presented challenges for the project, they have not been insurmountable. With additional wind turbines and an expansion of the hydrogen storage system, it is anticipated that the project could eventually supply 90% or more of the island’s total electricity needs.

Figure 12: Graphic of the fuel cell system at Ramea (left), Picture of the power system at Ramea (right). Source: Nalcor Energy
**LESSONS LEARNED**

**TECHNICAL**

Caution should be exercised if using re-conditioned turbines, or technology; difficulties can arise, which can drive O&M cost inflation. The first phase of the Ramea project made use of re-conditioned wind turbines; this reduced upfront Capex, but led to some difficulties in operations. Also, integration has proved a challenge in an environment of declining load – curtailment is frequent as a result, and issues with voltage quality and frequency (variations of +/- 0.1Hz) have occasionally occurred.

Declining loads can result in excess capacity, and small island systems are likely to require curtailment, or dumping of excess generation. The small fishing community of Ramea has experienced flat or declining load for approximately two decades. This means that diesel capacity is far in excess of what is needed; the addition of wind capacity on Ramea therefore benefits from surplus generating and reserve capacity. Excess capacity can ease integration challenges, but it can also create tensions, as diesel operators often seek to maintain a ~30% capacity factor on the diesel generators. The reason for this is to maintain a high enough temperature in the chamber to foster efficient combustion – otherwise, soot tends to build up, and can create problems for the system’s performance.

Availability of local expertise for engineering and O&M support is important for system performance, as well as cost control. It can take almost two days to get to Ramea Island from mainland Canada, which means that when the wind turbines experience difficulty, downtimes are longer. While Nalcor engineers are on-hand for the diesel-hydrogen components, as well as for their three (3) 100kW turbines, the six (6) 65kW turbines of phase 1 are owned and maintained by Frontier Power Systems, which is based in Prince Edward Island.

**SOCIO-ECONOMIC**

Aligning all project partners and strengthening cooperation between the different participants, including local residents, is vital to project success and to community acceptance. Nalcor engineers have suggested that the project would not have been possible without the cooperation and engagement of the local community.

**INSTITUTIONAL**

Set realistic goals. Initial timelines for the second phase of the project were overly ambitious, and delays forced the connection date back a number of times. Delays should be anticipated, and flexibility should therefore be incorporated into the project planning from the beginning.

Utilities are sometimes slow to adopt innovative technologies for a host of reasons. Direct utility involvement and leadership by Nalcor have been important factors in the project’s success. A clear learning curve has taken place, and learning is on-going as data is gathered.

**FINANCIAL**

Fuel cost savings were less than initially projected, though these have recently improved with rising diesel costs. It is important to err on the side of caution with projections of cost savings. While the project was partially funded via grants from government, the importance of proving cost savings for Nalcor has remained an important component of the project’s success.

**ADDITIONAL SOURCES:** (Nalcor Energy, 2010; Natural Resources Canada, 2009a, 2009b, 2010)
### FAROE ISLANDS, DENMARK

#### TEMPERATE REMOTE AREA

<table>
<thead>
<tr>
<th>REGION BACKGROUND:</th>
<th>POPULATION OF 49,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Faroe Islands are a group of 18 islands in the North Atlantic Ocean, and are considered a self-governing country though they remain under the sovereignty of Denmark. There are two main grids in the islands - one for Borðoy, Viðoy, Kunoy, Eysturoy, Streymoy, Sandoy, Nólsoy and Vágar, and an independent system at Suðuroy in the far South. There are also five smaller Islands that are not interconnected. In 2009, fossil fuels dependency was at 95% with only a 4% share of renewable energy (mainly hydro and some wind for electricity generation) and 1% use of waste heat for district heating (HagstovaForøya, 2011). Electricity needs are met with gas oil, heavy fuel oil and hydro power stations located in different islands by the Faroese Electricity Company SEV, plus two small wind farms. There are high heating needs which are largely met by central heaters using gas oil, gas and a small district heating system using waste heat from an incineration plant. Diesel is consumed for fishing fleets.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACCESS:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The Faroe Islands are located in the North Atlantic halfway between Iceland and Scotland. There are direct flights from Denmark and Iceland year round, while there is connection from the UK and Norway during summer season. The islands are also accessible by ferry from Denmark and Iceland (April-October) at least once a week.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CLIMATE:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subarctic climate with summer warmest average temperature not exceeding 10°C and coldest month at no lower averages of 0°C during winters.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MAIN REGIONAL ECONOMIC ACTIVITIES:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing (although overfishing of the Atlantic Cod created a major collapse of the Faroese economy in the 90s (Numminen, 2010) still represents 95% of exports and most industrial activities are linked to fishing, tourism and more recently oil are being developed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPES OF ENERGY NEEDS BY SECTOR:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy needs include residential high consumer end (lighting, cooking, heating), commercial, fishing industry, fish farming, and information technology.</td>
<td></td>
</tr>
</tbody>
</table>

---

“IEA-RETD REMOTE”
PROJECT DESCRIPTION:
The Faroe Islands are developing a diversified agenda of projects and initiatives that are seeking to increase the use of RET and diminish dependency on fossil fuels. Use of hydro resources for electricity production dates back to the 1920s, and more recently, several endeavors are being pursued by government, communities and the private sector. More concretely commitments have been laid in their Climate Policy (Ministry of the Interior, 2009) to reduce oil consumption by 20% (226Mtonnes in 2005 to 181 Mtonnes in 2020) by 2020.

- A 2.13MW wind farm installed in Neshagi (developed by SEV), first turbine (150kW) was erected in 1993 as a trial and is still operating. Three turbines (660kW each) were added in 2005, all together generating an average of 6.5GWh/year.

- In 2003 a 1.98MW wind farm was constructed in Vestmanna developed by private company Sp/F Røkt. The wind farm generates around 7.5GWh/year.

- A 220kW wind turbine is ready for installment as a part of the Nólsoy Island sustainable energy supply wind to heat project: and another one will be added. The generated electricity will be used only for heating water for 1/3 of the households in Nólsoy, since there is no clear framework for electricity to be fed into the grid or distributed among households, but also because requirements on electricity quality to be fed would increase the investment. Owner and installer is NólsoyarOrkufelag (Nólsoy Community Company). The community constructs their own distribution grid and cannot use SEV’s assets; this also hindered the initial project, which sought to install a wind/hydrogen system for electricity and heating as described in Durhuus, 2009. The main obstacle however was lack of funding.

- The Kambsdalur Renewable Energy Centre (KREC), solar thermal and wind/hydrogen installation to deliver heat and electricity includes a solar thermal installation of 200 m$^2$ and two micro-wind turbines of 5.2kW in which the generated electricity will be used for residential consumption. It is not legally possible to feed the excess electricity from the onsite systems back into the grid. Solar energy is used to provide heating to a local secondary school 7 months a year. The KREC is developed by a private company and will be transferred into a charity that acts as an independent research and demonstration centre and advisory service. Electricity production is currently set up to produce into the grid but the system is designed as a stand-alone system to make KREC a 100% renewable centre when the centre building is established. The operation is in cooperation with SEV.

---

55 Next step is to install heat pumps in all households which have a 3COP that will provide coverage to all households. In addition, another turbine will be added next year.
PROJECT FINANCING:
- Neshagi wind farm was financed by SEV.
- Vestmanna wind farm was financed by the private developer Sp/F Røkt (investment costs were not available).
- The Nólsoy community project received government funding from Ministry of the Interior of €240,000 and equity shares from the community €40,000. The project is benefitting from previous studies and now abandoned projects on making the island totally energy independent.
- The KREC project received government funding from Ministry of the Interior of €540,000, plus the local municipality has contributed with €230,000, the project has yet not been finalized and is still raising funds.

PROJECT O&M:
- The Neshagi project reported operating costs of 1.8M DK (€240,000) in 2009 (SEV, 2010), i.e. approximately €0.037/kWh, not including investment.
- The Vestmanna project has a €0.05/kWh selling price to SEV.
- SEV won a competitive bidding of a new wind power project with a selling price of €0.05/kWh with a project of 4.9MW, but it is phasing legal barriers.
- The Nólsoy and KREC projects are still in their commissioning phase. But for example, at Nólsoy the current cost of heating is €0.19/kWh (thermal), with the new project heating costs are expected to be reduced to €0.11/kWh (thermal) and further down to €0.07/kWh if hydrogen storage is used (Finden, 2007), which still has not been integrated.

TRANSPORTATION DETAILS: Main transportation on the islands is by automobile and ferry. The largest energy consumers are fishing ships.

CURRENT STATUS OF PROJECT:
Neshagi and Vestmanna wind farms have been producing and feeding their electricity generation into the grid. SEV seeks to install new wind farms, but due to legal barriers, such as requirement for new projects to come under competitive bidding, new investments have stalled.

The Nólsoy and KREC projects are in their commissioning phase and are expected to be fully operational early next year.

Other RE projects are in the pipeline like the like the wind pumped/hydro storage systems and the Ocean Rainforest algae to methane, farming of macroalgae with harvest and extraction for high value products and bulk for energy. Methane is to be used for electricity production and turned into methanol for transport sector – export to EU markets.

The Faroe Islands still have to approve their Energy Policy which is currently being drafted. Special focus is being placed in the regulatory framework to ease new projects to become operational.
INSTITUTIONAL FRAMEWORK/SUPPORT:
SEV is co-operative owned by the municipalities of the Faroe Islands. It is an integrated company in charge of generation, transmission, distribution and commercialization of electricity. The Electricity Authority is the supervisory body of the electricity sector in charge of dealing with the administration of licenses for electricity production and related issues. So far only the Vestmanna project is the only private electricity generator in the islands. SEV signed in 2003 a 10 year PPA to purchase the electricity from Sp/F Røkt at 0.35-0.40DK/kWh (approximately €0.05/kWh). The Nólsoy community has created their own Company to manage and operate their project and have limited their scope to only heating purposes due to legal and especially economic barriers.

ENERGY DEMAND AND GROWTH:
Electricity generation for the whole Faroe Islands in 2008 was 260GWh and is expected to increase to 365GWh by 2020. Peak demand is 35-40MW at noon.
Heating: 60,000 tonnes of oil are used per year in oil burners for household heating purposes
Land Transport: 30,000 tonnes of diesel are used in vehicles
Sea transport (including fishing vessels): 79,000 tonnes of oil

GRID GENERATION SOURCES:
In 2009, 35,000 tonnes of fuel oil and gasoil were used for electricity generation (55%) plus 40% from hydro power plants and 5% from wind energy.

TARIFF STRUCTURE:
Tariffs in the Faroe Islands are €0.17/kWh for electricity and approximate costs for heating are €0.09/kWh (thermal). A household spends on average €200/month on heating (Durhuus, 2009).
## LESSONS LEARNED

| TECHNICAL | Small-scale projects can provide techno-economic evidence for future expanding plans. Although the projects in Nólsoy and KREC have high investment costs, they serve as a showcase for replication in other parts of the islands
Innovative and alternative storage systems. Storage of wind excess electricity in low electricity consumption can be used for other purposes (e.g. hydrogen-powered ferries or vehicles) and for securing electricity supply
Introduction of efficient technologies to reduce energy needs. In Nólsoy district heating replaced old oil heaters reducing demand. The planned installation of geothermal heat pumps will cover heating needs of all the community in Nólsoy
Coupling of technologies and resources. In Nólsoy heat demand (to be met with wind electricity) is higher in winter when the wind resource is the largest. In the KREC use of solar heaters to meet heating demands in a secondary school and later a sports hall coupled with wind energy for winter generation when solar irradiation is lower and winds are stronger. |
| SOCIODEMOMIC | Renewable energy projects should be matched to community need. In Nólsoy, elderly citizens complained of the high percentage of their pension required to pay energy bills. The renewable energy project seeks to address heating, which is the primary driver of energy demand and therefore the underlying cause of high power bills. In addition, reduced dependency on oil burners eases the burden of securing fuel and transporting it to households. The project will also reduce pressure on community’s energy budget. |
| INSTITUTIONAL | RET Projects require policy support to streamline development. The current legislation requires new projects to go through a competitive bidding process which has hindered/slowed new initiatives of communities and even SEV. Nólsoy and KREC are not grid-connected and electricity is used only for heating purposes (which can be more inefficient or represent energy losses). This also increased investment in Nólsoy where a new separate distribution grid had to be installed. The community had to create its own company and it is not allowed to partake in the electricity market. |
| FINANCIAL | Non-energy financing can be used for energy projects. There are no specific funding schemes for RE projects in the Faroe Islands. In order to secure financing, projects have taken advantage of non-energy related financing schemes such as the Husalánsgrunnurin (House Loan Foundation) for residential projects, the Jarðargrunnurin (Agricultural Foundation) for projects on farms and commercial bank loans. |
| ENVIRONMENTAL | Understanding of environmental risks to RET. Special design of wind turbines to be able to cope with high wind speeds and turbulence in winter. Special protection for solar heaters must be considered due to possible debris blown. |
## Isle of Eigg, Scotland

### Temperate Remote Area

<table>
<thead>
<tr>
<th>PV/Wind/Hydro/Diesel Hybrid</th>
<th>Population of 96 (37 Households)</th>
</tr>
</thead>
</table>

### Region Background:
The Isle of Eigg is part of the Small Isles Archipelago off the coast of Scotland. Until recently, households used their own diesel gensets for electricity plus a small hydroelectric generator that served several households. Access to electricity was usually limited to a few hours per day. Purchasing diesel was both expensive and difficult due to inadequate infrastructure. A craft vessel transports diesel to the island periodically, pumps diesel into barrels, which are rolled to vehicles and taken to the households. A household would typically devote a full day to obtaining diesel (Fyffe, 2011). Prior to this project in 2008 there was no island grid electricity. The first mini-hydro turbine (2kW) was installed by a resident to provide electricity to the island’s pier and main public building. In 2003 the turbine was upgraded to 6kW capacity (Weiss, 2006).

### Access:
There is a one-hour ferry that connects the island with mainland approximately 30km away. On the island the only vehicles (approximately 40) allowed are service vehicles and those owned by islanders.

### Climate:
Temperate climate, cool summers and mild winters, precipitation most of the year, but lower in the sunniest months of April – August.

### Main Regional Economic Activities:
Primarily tourism (approximately 8000 visitors per year), fishing, farming, and construction

### Types of Energy Needs by Sector:
Residential (heating, washing machines, among other major appliances) and commercial

### Project Description:
Initial feasibility studies estimated the cost to interconnect the island with the mainland grid. However the project estimates were too expensive at £4-5M (€4.7–5.9M$^{56}$), and the proposal was abandoned. In 2004 it was decided to introduce a hybrid renewable energy system which had a final cost of £1.6M (€1.87M), including design and capital investment (installation, grid and access is now 24hours/day). The project is intended to increase access to grid-quality electricity, improve self-sufficiency, reduce diesel consumption, showcase the hybrid system, and improve environmental conditions.

### Project Ownership:
The project is owned by the Isle of Eigg Heritage Trust (IEHT). IEHT is a partnership between residents of Eigg, The Highland Council and the Scottish Wildlife Trust$^{57}$.

---

$^{56}$ Exchange rate £1 = €1.17  
INSTITUTIONAL FRAMEWORK/SUPPORT:
The Eigg Electric Ltd., a subsidiary of the IEHT, was set-up in 2008 to operate and manage the mini-grid. The system is completely independent from the mainland utility. Scottish Hydro Constructing is contracted to do major annual and monthly maintenance that requires professional electrical skills. Eigg residents carry out the simpler day-to-day maintenance of the system. Revenue has been sufficient to cover the O&M of the system.

The government has determined that the system is eligible for feed-in-tariff payments for the PV, wind and smaller hydro (6kW turbines) production. The system has meters installed for each eligible component. The payments are calculated monthly and paid yearly. The larger 100 kW hydro system is covered by renewable obligation credits (ROCs), which are paid on a monthly basis. It was reported that both FiT and ROC processes were simple and straightforward.

PROJECT INSTALLER:
The project was designed and built by Scottish Hydro Contracting with subcontractors E-Connect Ventures Ltd., Wind and Sun Ltd., Energy Renewed Ltd., G.G. McKenzie Contractors Ltd., Synergie Scotland Ltd. The project also used the voluntary contributions of Eigg residents.

LOAD DEMAND AND GROWTH:
The system is designed for a peak demand of 100kW. 316.22 MWh of energy was generated from November 2008 – October 2009. The peak system demand during this period was 40kW. Each household (37 total) has 5kW power demand limit, and businesses (5 total) have a 10kW demand limit. Electricity consumption has increased dramatically since electrical access was expanded to 24 hours. Power availability also has increased to 5kW from the 0.5kW typically provided by private gensets. Data is available for only the first year of operation, but anecdotal evidence suggests that the improved electrical access has encouraged residents to purchase many new appliances. Demand has also grown as new residents have moved to the island.

GRID GENERATION SOURCES:
The project installation initially included:

<table>
<thead>
<tr>
<th>Installed Capacity</th>
<th>Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10kW, PV</td>
<td>2%</td>
</tr>
<tr>
<td>1 X 100kW and 2 x 6kW run-of-river hydro capacity</td>
<td>80.5%</td>
</tr>
<tr>
<td>4 x 6 kW wind turbines (24 kW total)</td>
<td>10.5%</td>
</tr>
<tr>
<td>2 x 80 kW diesel gensets for back-up during low-rain periods</td>
<td>7%</td>
</tr>
</tbody>
</table>

A 48V battery with 4400Ah capacity (~211 kWh) provides enough back-up for 12 hours (Thim et al, 2010). Based on this data, it was determined that the diesel gensets were run frequently in June and July, when there was inadequate rain to run the hydro turbines at sufficient capacity. In response, PV capacity was increased to 30kWp.

58 Isle of Egg Website last accessed November 2011 at: http://www.isleofeigg.net/eigg_electric.html
TARIFF STRUCTURE:
Tariffs were set to ensure the system is self-sufficient and provides funding for component replacement. Current charges for electricity are 20p/kWh (€0.234/kWh) (Fyffe, 2011), which are slightly higher than mainland electricity prices. However, in the future Eigg electricity prices are not expected to increase as much as mainland tariffs. Residents also pay a fixed power charge and a standing charge for their metering equipment. Users claim that they now pay around 25 – 40% of what they used to spend on energy services (Fyffe, 2011).

PROJECT FINANCING:
The total project budget was £1.6M (€1.87M) and includes funds from many different institutions. Funders include the European Regional Development Fund (ERDF, 46%), HIE Lochaber (19%), the Big Lottery Fund (15%), the Scottish Community and Householder Renewables Initiative (SCHRI, 12%), IEHT and residents (6%), the Energy Savings Trust (2%), and the Highland Council (1%).

PROJECT O&M:
Diesel use for electricity was reduced from 51,000 liters/year to 7,800 liters/year (an 85% reduction) (Thim et al, 2010), and electricity is now provided 24 hours a day.

CURRENT STATUS OF PROJECT AND NEXT STEPS:
The project has been operating effectively for the last 3 years, and the system was reported to be in excellent condition with few operational problems. The residents report high satisfaction. In 2010 the community received a major national award for the project and used the prize money to purchase an additional 20kWp of PV for the summer months.

---

60 This consumption represents only diesel used for providing electricity for a few hours per day. Not only has the consumption of diesel been reduced, but now there is power availability 24 hours per day.
Figure 14: Images of Eigg Islands. Source: Maggie Fyffe at IEHT
### LESSONS LEARNED

#### TECHNICAL

Equipment providers and installers are more convenient when locally provided. One of the hydro turbine manufacturer was Australian, which complicated access to replacement parts. Major maintenance can be easily managed by local Scottish company.

**Demand limits with feedback to users improve system operation.** If users exceed their allowed power demand limit, they are disconnected and charged a £25 reconnection fee. However, they are provided an alarm when they get near the limit to help them adjust their usage. An “energy traffic light” system has been installed. A green light indicates there is adequate renewable energy, a yellow light warns users that the system may soon need electricity from the diesel gensets, and a red light indicates that the system is using diesel electricity (Houghton, 2010).

#### SOCIO-ECONOMIC

Local involvement is key to success. The community was highly involved and was the project promoter. Voluntary (in-kind) support was a valuable contribution to reduce system costs. For example, residents volunteered to lay cable and shared knowledge of the terrain with installers. Strong relations with system designers, contractors and funding agents facilitated project execution.

**Maintaining system ownership within the community will ensure funds stay local.** Project revenues are mainly staying in the community (through the Eigg Electric Ltd.) instead of being claimed by external providers of diesel. The system has attracted more people to the island (tourists and new residents)

**A 24 hours access to electricity will increase consumption.** Now that power is available all day, consumers are able to have other appliances. The demand for electricity has increased, but is still lower than in grid-connected houses.

#### INSTITUTIONAL

Permits to operate independent of utility should be facilitated. The permitting process for the project was a cumbersome and bureaucratic process. The utility was not going to extend the grid so the community had to create their own independent utility

**Government policy should be flexible to consider cases of remote communities.** UK policy created pathways for FiTs and ROCs to apply in remote areas, which generated additional revenue for the project.

#### FINANCIAL

Small communities face greater financing challenges. The community was reluctant to begin the project since they faced the high risk of paying for the initial design of system before making investment. RET projects may requires combining funds from many diverse institutions, as well as local businesses and residents. Finding funding is challenging. Remote area power projects will be more successful if proponents have knowledge and experience with applying for funds to finance the project.

**Partnerships can facilitate access to funds.** The project was successful because it was a community initiative that received governmental, private, and non-governmental support.

#### ENVIRONMENTAL

The project created awareness of environmental issues that has triggered other “green” programs. Residents are now more likely insulate their households, participate in community gardens, and working to reduce vehicle use (Fyffe, 2011; Hutchison, 2010).
FLOREANA ISLAND, GLAPAGOS, ECUADOR

SMALL WARM REMOTE AREA

PV/DIESEL HYBRID MICRO GRID PROJECT

POPULATION OF 200 (55 HOUSEHOLDS)

REGION BACKGROUND:
Floreana is the smallest island of the Galapagos Archipelago (Rep. of Ecuador), East Pacific. Prior to the implementation of the PV/Diesel hybrid project, a diesel genset operated 13 hours per day in the only village of the island (Puerto Velasco Ibarra). Any households outside the village had no access. The electrical system required a subsidy from the national government of ~US$25,000 (€18,650) per year.

ACCESS:
Mainland Ecuador is about 1000 km east. The common means of transportation are by boats, although boat fuel is typically purchased on the main Galapagos Islands. Within Floreana, there is a public transport service to mobilize people to the farmlands 6-7km away from the village.

CLIMATE:
Floreana is located near the equator, but has a more moderate climate than would be expected due to the prevailing ocean currents. The region has two major seasons. The dry season runs from July to December, and the hot or wet season lasts from January to June. The temperature averages 21°-30°C with annual average rainfall of 60-100mm.

MAIN REGIONAL ECONOMIC ACTIVITIES:
The main regional economic activities include fishing, agriculture and tourism.

TYPES OF ENERGY NEEDS BY SECTOR:
Most of the energy use is residential (lighting, radio, TVs, refrigerators, deep freezers, some A/C units) with two hotels and a restaurant (a new hotel was built recently).

PROJECT DESCRIPTION:
Beginning in 2003, Floreana developed a pilot project to validate technology and organizational scheme.

- Phase I (2003): A Multi-user Solar Hybrid Grid (MSG) and 5 individual PV facilities for farmhouses outside the main village were commissioned. The service quality was single phase AC, 24/7 to all users; 3 phase service to community workshop operated occasionally from the genset. Demand side measures included partial rebate to purchase energy efficient appliance upgrades (CFLs, refrigerators and deep freezers) to optimize cost efficiency of total investment. This new service approach with PV hybrid technology reduced the risk of environmental damage from fuel transport and spillage and reduction in yearly operational deficit savings from reduced diesel use.

- Phase II (2011): The facility was recently updated to substitute _Jatropha_ biodiesel for the remaining diesel generation.

61 2002 US$. There was also a diesel subsidy in Ecuador creating a fixed price of US$0.91/gallon.
PROJECT OWNERSHIP:
Ownership is split between the local island authorities, Junta Parroquial de Floreana (JPF) (PV generation facility) and the utility Elecgalapagos S.A. (distribution grid, genset and meters).

INSTITUTIONAL FRAMEWORK/SUPPORT:
Nationally, CONELEC is the Ecuadorian agency that regulates electricity distribution and commercialization to concession utilities. It also establishes tariffs. In the Galápagos Islands, EEPG has the concession to generate, transmit, distribute, commercialize electricity and collect electrical tariffs. EEPG is responsible for fuel supply and also maintenance tasks of the PV facilities for the JPF in exchange to the energy received.

PROJECT INSTALLER:
- Phase I (2003): TTA commissioned by, Spanish NGO SEBA, ParqueNacional Galapagos and EEPG
- Phase II (2011): ProViento and EEPG

LOAD DEMAND AND GROWTH:
At the completion of Phase I in 2004, the annual demand was 53,917 kWh/year. Between 2004 and 2008, demand grew 54% to 83,125kWh/year.

GRID GENERATION SOURCES:
- Phase I (2003): PV (1 MSG x 21kWp and 2 x 800Wp MSG, 3 x 400W Solar Home Systems) and two diesel gensets (60kW and 50kW), two batteries of 24 2V elements each (total of 300Ah / 48Vdc each). PV has generated 30% of electricity needs in the period of 2004 – 2009.
- Phase II (2011): Two new biodiesel gensets (68kW each) have substituted the older ones

TARIFF STRUCTURE:
The initial tariff scheme agreed with users was flat monthly charges for all users, whether they were connected to the MSG or supplied by individual micro plants. Electricity usage was capped by a daily allowance with demand-side controls, and pricing was independent of final electrical usage. However, the flat-rate tariffs were eliminated by the electric utility despite initial agreements with users. The Ecuadorian national government had an existing national policy of universal tariffs for the islands, which the EEPG decided to match. This resulting very cheap tariff (US$0.10/kWh) applied was not sufficient to cover the project O&M costs, high subsidies continued to be needed and did not provide any incentive to constrain demand and contributed to load growth.

PROJECT FINANCING:
- Phase I (2003): The project was funded by ParqueNacional Galapagos, European Commission, AECID (Spanish Cooperation Agency), and monetary and in-kind contributions from the users and JPF.
- Phase II (2011): financed by Ministry of Electricity and Renewable Energy (MEER), DED (Deutscher Entwicklungsdienst) and VWP (Vereinigte Werkstätten für Pflanzenöltechnologie)

62 The Multi-user Solar Hybrid Grid incorporates a single PV installation
PROJECT O&M:
The new system reduced the subsidy required to cover operating losses. However, the tariff structure
does not provide enough revenue to cover O&M subsidy even if lower now has been maintained.

CURRENT STATUS OF PROJECT:
One of the battery banks was non-operational in 2009 since one of the elements got damaged and was
not replaced, which made the system non-operational for several months.

Phase II was completed in early 2011, and includes two new gensets fueled with Jatropha biodiesel.

Figure 15: Images of the construction of the Floreana PV/diesel hybrid project. Source: Trama TecnoAmbiental S.L.
**LESSONS LEARNED**

<table>
<thead>
<tr>
<th>TECHNICAL</th>
<th>Load growth is more detrimental to operation in remote systems than in large national grids. Growth should be managed with appropriate policy in remote systems. The meters supported demand limiting, but this functionality was later not used. The tariff structure did not provide incentives to limit electrical usage. Integration technologies are relevant for hybrid RE power plants. The lack of an automatic start-up of the diesel genset causes interruptions especially at night when the utility operator is not present. Remote monitoring would have enabled off-site technical experts to provide more guidance and oversight to local technicians. Follow-up monitoring and evaluation programs are critical and should use remote monitoring. Remote monitoring could have assisted to reduce operation and maintenance costs and might have also helped prevent the batteries from becoming damaged.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOCI-ECONOMIC</td>
<td>Public expectations of their infrastructure services should be incorporated into planning. The residents had prior experience with resource conservation (water was already managed with an allowance scheme beforehand) which enabled the consideration of a similar approach to manage the use of electricity. National policy, however, hindered this more appropriate tariff structure. Productive uses should be promoted. One of the farmhouses that was electrified during the project purchased a high-efficiency egg incubator for chickens. The PV facility was integrated onto a multi-use building built as part of the project. This improved the “community feel” for the project and added value for users (for meetings, seminars, tourists, etc.)</td>
</tr>
<tr>
<td>INSTITUTIONAL</td>
<td>Appropriate organizational structure and clear division of responsibility is necessary to ensure long-term sustainability. It was unclear who was responsible for battery maintenance, which led to early failure. Policies that are appropriate for larger national grids may not be appropriate for small island grids. Ecuador has a US$0.4403/kWh feed-in tariff (FiT) policy for PV, however this is not provided in Floreana due to an unclear and cumbersome regulatory framework. Innovative tariff structures that would not be appropriate on a national grid can be helpful to small island systems. The flat rate tariff and energy daily allowance (EDA) concept was well accepted among the community, but was later discarded by EEPG due to national policy. O&amp;M costs were therefore not covered and required a continued subsidy from the government, reducing the economic sustainability of the project. There are advantages and disadvantages to installing pilot projects in remote communities. The high cost of power and necessity for subsidies provide a strong financial incentive to use new technologies. The Floreana project reduced the subsidies necessary and allowed 24-hour/day service. Pilot projects will generally require long-term support and have higher maintenance costs. The remoteness of the community and the lack of local specialized technical expertise can lead to equipment failures. Energy efficiency regulations and incentives should accompany renewable energy investment. Rebates for high-efficiency refrigerators and other equipment reduced the size and cost of the generation facility. A staged project approach will lower system cost while reducing environmental impact and providing reliable electricity. Energy efficiency and rational energy usage was used first, followed by renewables, and then underpinned by the efficiency use of diesel fuel. This combination balances environmental, economic and social aspects of electrical systems.</td>
</tr>
<tr>
<td>FINANCIAL</td>
<td>Communities can support investment. The community in Floreana contributed to the project both through in-kind contributions and covered a small percentage of the investment costs. Use of development funds and partnerships. Funds from AECID, partnering with UNDP, government funds, and WWF, made the first phase of Floreana possible. DED funds were used for the second phase.</td>
</tr>
</tbody>
</table>
Renewable energy technologies are particularly important for tourist destinations near protected parks and other eco-tourism draws. Reducing the fuel used can reduce the likelihood of damage from fuel spills.
REGION BACKGROUND:
Located where Ningaloo Reef fringes against the Western Australia mainland, Coral Bay is a popular reef diving and snorkeling site. The site was first discovered in the mid-1800s, but the town was not formally settled until 1968.

ACCESS:
Perth is the nearest major city, located about 1,200 km south of Coral Bay. There is a small airport and paved road access. Similar to the rest of rural Australia, automobiles provide the primary form of transportation within Coral Bay.

CLIMATE:
The climate is hot and dry. During the summer months, the temperature typically ranges from 22°C to 35°C. During the winter, the temperature varies between 6°C to 17°C. Average annual rainfall is between 25 and 50mm.

MAIN REGIONAL ECONOMIC ACTIVITIES:
Coral bay heavily relies on tourism, with 312 camping sites, 62 rooms in cabin/chalet/unit style accommodation, 38 backpacker rooms and 34 hotel rooms, plus a small number of houses that are mostly used as holiday rentals.

TYPES OF ENERGY NEEDS BY SECTOR:
Energy is used primarily for tourist accommodation with some residential use.

PROJECT DESCRIPTION:
A 3 MW off-grid wind/diesel system was commissioned in August 2007.

PROJECT OWNERSHIP:
The wind/diesel generation system is owned and operated by Verve Energy, a WA government-owned electricity producer with AU$2.2 billion (€1.65 billion) in assets. Verve has a contract to sell energy to the rural electricity generator/distributor/retailer Horizon Power. Horizon is also state-owned.

INSTITUTIONAL FRAMEWORK/SUPPORT:
Verve Energy and Horizon Power collaborated to upgrade the power system at Coral Bay. The project was supported by a number of federal grants and programs.

PROJECT INSTALLER:
The system is a joint installation between Verve Energy’s Sustainable Energy Branch and Horizon

\[ \text{Conversion assumed} AU\$1 \text{ (Australian dollar) } = \text{€0.75} \text{ (Euros)} \]
Power. Verve Energy was responsible for the wind turbines and low-load diesel power station, and Horizon Power coordinated the project, put in the underground power lines and billing systems. Local suppliers and contractors were used when possible.

LOAD DEMAND AND GROWTH:
The load has a 700 kW peak. Planning authorities have capped the number of visitors to the town at 3,600 per night and the number of residents to 400 in order to limit demand growth. During periods of low-load, the wind turbines are curtailed to prevent damaging other equipment.

GRID GENERATION SOURCES:
The system is composed of 7 x 320kW (2,240 MW total) LLD diesel generating sets modified for low load operation, 1 x 500kVA PowerStore flywheel unit, and 3 x 275kW (825 kW total) tilt-up cyclone-rated Vergnet wind turbines. Powercorp’s LLD technology is based on standard diesel generator technology but is altered to run for sustained periods at loads as low as 5%. In addition to the smaller size allowing them to more efficiently match loads, the LLDs are sized to roughly match the size of the turbines, which also reduces low load operation. The flywheel allows for bridging power if the wind turbines stop producing electricity suddenly and the generators are unable to ramp-up in time. They also improve the power quality of electricity that the wind turbines produce. The Vergnet turbines are unique because they include hoist equipment that allows them to be raised and lowered in place when inclement weather approaches.

TARIFF STRUCTURE:
In Western Australia, tariff rates are regulated by the state government. Residents pay AU$0.2187/kWh (€0.164/kWh) for electricity. The tariffs are not high enough to cover the full cost of remote power.

PROJECT FINANCING:
The project is jointly funded by the Australian government and Verve Energy with oversight from WA’s Sustainable Energy Development Office.

The Australian Government contributed AU$3.96 million (€2.9 million) for the wind turbines and enabling infrastructure (i.e. not the diesel generators):

- Renewable Remote Power Generation Program grant: AU$2.76 million (€2.0 million)
- Renewable Energy Development Initiative (REDI) grant: AU$1.2 million (€0.9 million)

The project is worth more than AU$7 million (€5.3 million), including the additional AU$1.3 million (€0.98 million) allocated to establish an electricity distribution network.

Verve Energy reported that the 50% Federal Government capital subsidy was necessary for the project to be commercially viable. The cost works out to be AU$10,000/kW (€7,500/kW) of peak demand.

PROJECT O&M COSTS:
Data on O&M costs is unavailable at this time.
CURRENT STATUS OF PROJECT AND NEXT STEPS:
The wind turbines contribute up to 90% of the instantaneous power for portions of the year, although the average contribution is 40-60%. The system is working well, but extensions are not planned at this time.
<table>
<thead>
<tr>
<th>LESSONS LEARNED</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TECHNICAL</strong></td>
<td><strong>Diesel generators should be adapted to meet the needs of a remote hybrid system.</strong> Multiple smaller diesel generators may be more suitable for a remote grid than a single large generator. Hybrid systems require more controls than simple diesel systems. Diesel generators that are capable of consistent low load operation can facilitate integration of renewable power at high penetration rates. <strong>Common local extreme weather should be considered in designs to protect the RET investment.</strong> Vergnet turbines were selected because they are able to lay down flat during cyclone and other high-wind events.</td>
</tr>
<tr>
<td><strong>Socio-Economic</strong></td>
<td><strong>Load demand may be limited by limiting the number of tourists at one time.</strong> Overnight visitors to the town are capped at 3,600. This limits the tourism industry, but also limits the burden on local infrastructure.</td>
</tr>
<tr>
<td><strong>Institutional</strong></td>
<td><strong>A single owner/operator can more easily achieve high-renewable penetrations in a hybrid system than trying to integrate renewables owned by one party with diesel generators owned by another party.</strong> Verve Energy owns the entire generation project. <strong>Institutional experience with hybrid systems is critical for achieving high-penetration renewable systems.</strong> Coral Bay was able to build a system with 40-60% average penetration due to the prior wind-diesel system experience of Verve Energy and Powercorp. The local area did not have extensive existing experience with renewable energy.</td>
</tr>
<tr>
<td><strong>Financial</strong></td>
<td><strong>Federal grants for renewable energy or remote projects may encourage private or public organizations to invest in remote areas.</strong> This project would not have been cost-effective without numerous federal grants.</td>
</tr>
</tbody>
</table>
### BONAIRE, NETHERLANDS

**LARGE WARM REMOTE AREA**

<table>
<thead>
<tr>
<th>WIND/DIESEL HYBRID PROJECT</th>
<th>POPULATION OF 14,500 WITH 75,000 TOURISTS ANNUALLY</th>
</tr>
</thead>
</table>

### REGION BACKGROUND:
Bonaire is a Caribbean island in the Lesser Antilles. The island has an area of almost 300km$^2$. In 2004, Bonaire’s only power plant burned down, which encouraged the island to rethink its long-term energy strategy and begin moving towards a 100% renewable electricity supply. As an interim power solution, Bonaire’s electricity needs were met by a set of 12MW rented container (light-fuel) diesel generator systems.

### ACCESS:
Bonaire is an island, so access is only available by sea or air. It is located about 80km north of Venezuela. The island uses primarily automobiles within the island, and some boat transportation. Tourists use car rentals, taxis, and water taxis to get around.

### CLIMATE:
The weather in Bonaire is tropical, with an average annual temperature of 30°C. Bonaire receives little rainfall, about 50 cm each year, and has a prevailing easterly trade wind that provides roughly a 7 m/s breeze.

### MAIN REGIONAL ECONOMIC ACTIVITIES:
Tourism is the main regional economic activity.

### TYPES OF ENERGY NEEDS BY SECTOR:
Energy is primarily used for residential consumption (including hotels) and some small industrial activities.

### PROJECT DESCRIPTION:
The project was installed in 2 phases, with a 3rd phase currently under research and development (R&D). The first phase (2007) was to install a single 330kW Enercon turbine to pilot the installation and early operation for a low penetration renewable system. The single turbine had availability of over 99%. After this success with the first phase, the second phase (2010) transitioned the project to high-penetration, with expected 40-45% of electricity expected from wind turbines, and backed up with a 14MW of diesel, 3MW of battery storage, and a range of control equipment. The integrated system has been operational since October 2010. The original idea was to transition in a next phase from diesel fuel to biofuel produced from algae harvested from the ocean but this is no longer pursued.

### PROJECT OWNERSHIP:
Originally, the project owner EcoPower Bonaire BV was a consortium of Econcern, Enercon and MAN. However, in the 2009 credit crunch Econcern went bankrupt and their portion of the project was taken over by the main creditor RABO bank. EcoPower Bonaire BV installed the project as a build, own, operate (BOO), with a long-term power purchase agreement (PPA) for the local utility, Water en EnergieBedrijf Bonaire (Water and Energy Company of Bonaire, WEB)
INSTITUTIONAL FRAMEWORK/SUPPORT:
WEB is a Government-owned company, responsible for the production and distribution of water and electricity on the island. The project itself is owned by EcoPower, and has a long-term power purchase agreement (PPA) to sell power to WEB. The project enjoys strong support from the government of Bonaire.

PROJECT INSTALLER:
The project installers included the major equipment manufacturers, Enercon and MAN, with contracting overseen by the developer EcoPower.

LOAD DEMAND AND GROWTH:
Bonaire's peak electricity demand is approximately 11MW. Typically, Bonaire consumes 80,000 megawatt hours (MWh) of electricity. Data on grid growth is unavailable at this time.

GRID GENERATION SOURCES:
- Phase I (2007) involved the installation 1 x 330kW Enercon E-33 wind turbine.
- Phase II (2010): 12 x 900kW Enercon E-44 wind turbines, 5 x 2.8MW MAN diesel generators (14 MW total) capable of using biodiesel, 3 x 1MW containerized diesel generators for back-up and cold-starts, and 3 MW of Saft SMRX NiCad battery storage. These batteries provide back-up power, provide 2 minutes of 3MW bridge time until diesels can start if wind turbine output falls, and provide a short-term dump load during system faults. The wind turbines integrate with the rest of the system with an Enercon Power management system.

TARIFF STRUCTURE:
The project aims at a 10-20% reduction in electricity generation costs to reach some US$0.20/kWh (€0.15/kWh). The final tariff will be at US$0.30-0.35/kWh (€0.22-0.26/kWh).

PROJECT FINANCING:
Total project investment costs were US$60 million (€45 million). The PPA is expected to return roughly US$16 million (€12 million) annually, based on 80,000MWh/yr production at US$0.20/kWh (€0.15/kWh). The project was financed by Rabobank, with a 20% equity and 80% debt non-recourse loan. The project was complicated because the major EcoPower shareholder, Econcern, went bankrupt in the 2009 credit crisis. Rabobank took over their share of the project and opted to finance the loan.

PROJECT O&M:
The project O&M will be provided by EcoPower as part of their agreements under the terms of the PPA. Part of the project will is attempting to build capacity in the local community, with a focus on training local people to perform maintenance tasks. EcoPower is planning to fund educational programs in local schools so that Bonaire can build local technical capacity and environmental awareness into the island culture.

CURRENT STATUS OF PROJECT AND NEXT STEPS:
In August 2010, the new MAN diesel power station was fully operational, and in October 2010 the 10.8MW Enercon wind farm was completed. The system gets peak instantaneous 80% wind penetration, although the average is 30-35% of annual electricity. Despite the financing and permitting issues, the system has provided a strong hedge against rising fuel prices, and has reduced the cost of electricity production while increasing the use of renewable technologies.
Figure 17: New biodiesel power plant in Bonaire. Source: Ecofys
<table>
<thead>
<tr>
<th>LESSONS LEARNED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TECHNICAL</strong></td>
</tr>
</tbody>
</table>
| The project could have reduced installed capacity costs if they had more thoroughly investigated energy efficiency options. The project is an excellent example of integrating renewable energy with a thermal plant, although the broader project will be improved if WEB considers more demand-side efficiency upgrades to limit demand growth, with particular focus on tourism energy needs and the desalination plants.  

A gradual transition plan with strategic pilots can make the technical transitions smoother. The Bonaire project is implementing the project in phases to allow them to understand the technical complexities and operational challenges of the plants without a reduction in power quality. |
| **SOCIO-ECONOMIC** |
| Local education programs should be included in project plans to achieve long-term sustainability and reduce long-term O&M costs. EcoPower is including local community education and technical skills capacity building to enable the project to be maintained with local people. |
| **INSTITUTIONAL** |
| In the absence of fuel subsidies, private companies can successfully create a high-penetration renewable system with minimal governmental incentives. This project was financed largely through private capital and current appears to be proving a strong investment. This remains true even with the bankruptcy issues and purchasing the wind turbines when capital costs were high. |
| **FINANCIAL** |
| If the existing generation assets require extensive repairs or replacement, there is additional incentive for pursuing renewable technologies. The sunk costs in an existing power plant provided a disincentive to switching underlying generation technologies. The power plant fire in 2004 provided the island of Bonaire an incentive to rethink their energy supply. They took advantage of this opportunity to begin a transition to a system with more renewable energy. |
| **ENVIRONMENTAL** |
| Larger island and remote systems can successfully transition to higher penetrations of renewables. Bonaire has successfully increased their use of renewables, improving their impact on the local environment. |
EL HIERRO, CANARY ISLANDS, SPAIN
LARGE WARM REMOTE AREA

REGION BACKGROUND:
El Hierro Island is the smallest of the Canary Islands Archipelago of which 60% is protected land. It is completely dependent on fossil fuels. Electricity is currently produced by diesel generators at Llanos Blancos Power Plant owned and operated by Endesa, a private Spanish electricity company (Piernavieja, 2010). 55.6% of the island’s diesel fuel supply is used for electricity generation, 29.9% for transportation, 12.1% for other industrial and residential uses, and 2.4% for water desalinization. El Hierro has set the target of becoming the first 100% renewable energy powered island in the world. The ageing index is the highest of the Canary Islands, increasing 2.5% in the last 10 years (average age is 42.3 years) (Gobierno de Canarias, 2010), mainly due to retirees moving to the island.

ACCESS:
El Hierro is the most occidental of the Canary Islands. There is an airport with flights from/to La Palma, Tenerife and Gran Canaria. The main port of La Estaca is used for delivery of passenger and goods.

CLIMATE:
The climate is warm, with moderate and strong wind all year round and a rainy season from November to March. Temperatures oscillate between 19 – 23 °C.

MAIN REGIONAL ECONOMIC ACTIVITIES:
Main regional economic activities include public and private sector services (71%), tourism (~12 thousand/year), and other commercial activities (shops, repair, education), agriculture including fishing and cattle farming (7%), construction (19%) and industry (3%) (employed persons per sector %) (Gobierno de Canarias, 2010).

TYPES OF ENERGY NEEDS BY SECTOR:
Energy demand is split between residential (lighting, cooking, some A/C, refrigeration) and commercial uses with some industry present (mainly water desalinization plants).

PROJECT DESCRIPTION:
In 1997 the local government developed its strategy to make the island energy self-sufficient as part of its Sustainability Plan. The plan gained momentum in 2000 after UNESCO declared El Hierro a World Heritage Site, and since then the government has been aggressively funding the program. In 2009 the local government commissioned a hydro-wind/diesel hybrid system to provide the island with electricity from 100% renewable sources. The project is currently under construction and is expected to be operational by the first semester of 2012. In the longer term electric vehicles are to be incorporated to fully become independent from fossil-fuel imports.
**PROJECT OWNERSHIP:**
The company Gorona Del Viento S.A (GDV)\(^4^4\) is the owner and developer of the project. 60% of GDV is owned by Cabildo de El Hierro (Municipality of El Hierro), 30% by the private electricity company Endesa and 10% by the Government of Canarias, represented by the Technological Institute of the Canary Islands (ITC).

**INSTITUTIONAL FRAMEWORK/SUPPORT:**
The electricity market in Spain is liberalized in the generation and commercialization sub-sectors. Transmission in Spain is managed and operated by the state company Red Eléctrica Española (REE), which includes high voltage transmission in the Canary Islands. The transmission lines were recently purchased by the REE to go under state control. In Isla de Hierro, the current electricity generator and provider is the private company Endesa. The institutional model has yet not been defined and how the roles of the different players will be assigned. Two possible scenarios are being evaluated:

1. Gorona del Viento functions as an IPP and sells electricity to ENDESA
2. Gorona del Viento (GdV) replaces ENDESA (who also forms part of GdV) as the new generator and provider of electricity

**PROJECT INSTALLER:**
The project is being installed by the project owner GDV.

**LOAD DEMAND AND GROWTH:**
Electricity demand from 10/2010 to 09/2011 exceeded 44GWh and the peak demand was 7.6MW (CNE, 2011). Energy demand is expected to reach 69GWh by 2031, and is projected to grow at 2%/year for the first 10 years of the project and then at a rate of 1% (CNE, 2011: REE, 2011).

**GRID GENERATION SOURCES:**
Currently there is a 12.7MW diesel genset power plant in operation. The current construction project is installing an 11.32 MW hydropower plant and 11.5 MW of wind power. The project will also use a volcanic crater as a reservoir for pumped hydro storage. A 6MW water pump will fill the reservoir to store energy when wind production exceeds consumption and generate electricity when required with the hydro power plant. The renewable energy portion is expected to provide approximately 77% of electricity needs in the first year of operation, a percentage that will decline if demand grows (CNE, 2011). A further inclusion of PV and solar thermal installations is expected to increase the RE generation.

**TARIFF STRUCTURE:**
Spain has a regulated-tariff applicable to peninsular and insular consumers composed of consumption and power demand charges. On the other hand, rates recognized to electricity providers in Spain are set based on the revenue needed by electricity companies to satisfy their electricity activity’s economic remuneration and based on electricity consumption. The electricity companies’ budget must be approved by the CNE, were the government absorbs any operational deficit. This applies to the Canary Islands under the specific regime for insular and non-peninsular territories. The current project is expected to decrease the generation costs considerably, which will be reflected in diminishing the recognition of operational deficit. Tariffs to users will most likely remain the same, since they are already subsidized by the government. It has yet not been determined what will be done with the deficit savings obtained. As well, it is also not yet clear if the project will be able to apply for the Spanish feed-in tariff.

**PROJECT FINANCING:**
Total project budget is €64M (US$86.4M) of which Spain’s government funds from the Institute for the Diversification of Energy (IDAE) has provided €35M (US$47.25M) through public funds, and the rest is coming from the conformed company Gorona Del Viento. Private funds account <10% of the total investment. The expected TIR is 7.5% and a payback period of 11 years has been estimated.

**PROJECT O&M:**
The average generation costs for diesel-based electricity at the Canary Islands is €24.21cents/kWh (on average, depending on international diesel prices, it reached >€30 cents/kWh when the oil price peaked at US$140/barrel), more than three times the generation costs in mainland Spain (AEI – Clúster RICAM, 2010). The government has a specific fund to cover for the over-cost of generating in the Canary Islands which reached €737M for 2008 (disaggregated values per island were not available). The new RE project will account for savings of up to €3.54M/year, the financial sustainability of the project is still being evaluated and will depend on FiT recognition and applicability to carbon and other funds.

**TRANSPORTATION DETAILS:**
Fleet of 8378 vehicles consumes 30% of the current fossil fuel imports (Cabildo de El Hierro, 2010). Hydrogen and electric vehicles are being tested on the island. 75% of the population uses a private car as mode of transport. The Cabildo de El Hierro, Endesa and Renault-Nissan signed in September 2011 a Memorandum of Understanding (MoU) through which initial steps will be taken to convert the transport sector to a zero emissions one.

**CURRENT STATUS OF PROJECT AND NEXT STEPS:**
The project is under construction and is expected to become fully operational by the first semester of 2012. The main bottleneck delaying operability was the arrival of the wind turbines (due to high market demand) which arrived October 2011.
Figure 18: El Hierro project concept design. Source: ITC/Gorona del Viento
### LESSONS LEARNED

<table>
<thead>
<tr>
<th>TECHNICAL</th>
<th>Use of innovative storage systems can increase penetration of intermittent RET. Use of an existing volcano crater as a reservoir at a high altitude to pump water with wind energy excess as storage. Optimization of instant demand response (system control technologies) permit the coupling of demand with resource availability. The system has been designed to follow instant demand and respond in accordance to resource availability (feeding-in wind energy to grid or use it for pumping). Diesel use is limited to periods with no water nor wind.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOCIO-ECONOMIC</td>
<td>Inclusion of a research and development technological institution will increase dissemination of know-how. ITC has supported/validated techno-economic and environmental feasibility studies. Capacity building programs on renewables and other environmental issues (recycling, forestry, and green entrepreneurship) have already taken place. Dissemination of project information must come at early stages and be transparent. A clear and transparent communications campaign has been executed in the island which has kept the inhabitants well-informed and avoided resistance to project. RET projects can bring benefits that, while not expressible explicitly in monetary terms, can have significant positive impacts on quality of life and should be considered of equal or even greater importance than economic benefits. The Island will greatly reduce dependency on fossil fuels, giving islanders an increased sense of independence, increasing quality of life. Use of an innovative storage system that does not require major construction of infrastructure. Project will improve the process of water desalinization, ensuring access to water (an issue that has previously caused major migration away from the island).</td>
</tr>
<tr>
<td>INSTITUTIONAL</td>
<td>Government support can be a pivotal support. The government facilitated a €35M non-reimbursable fund through IDAE attached to the Ministry of Industry, Commerce and Tourism.</td>
</tr>
<tr>
<td>FINANCIAL</td>
<td>The creation of public-private partnerships will increase security for private investors and attract further funds. Shared public investment with almost 50% of funds leveraged from the private sector. The use of government funds can also be a “good business”. The project will lower the operational deficit covered by government. Project is expected to have a TIR of 7.5% and a PBP of 11 years.</td>
</tr>
<tr>
<td>ENVIRONMENTAL</td>
<td>The recognition of biodiversity’s value and cultural heritage will strengthen and even motivate projects. UNESCO’s world heritage declaration in 2000 was a major trigger to the project. Some environmental compromise may be necessary to achieve improvements. Wind turbines and the project itself had some opposition due to landscape visual impacts and land use, which required consensus from different stakeholders and a multi-criteria evaluation on the many other benefits intrinsic to the project.</td>
</tr>
</tbody>
</table>
MIYAKOJIMA, JAPAN

LARGE WARM REMOTE AREA

PV/WIND/HYDRO/DIESEL HYBRID PROJECT

REGION BACKGROUND:
Miyakojima is an island located in the Philippine Sea, the largest and most populated of the Miyako Islands (Ikema, Kurima, Ogami, Shimoji, and Irabu Islands are interconnected with transmission lines or submarine cables). Efforts to introduce renewable energy in the island date back to 1993, when Mitsubishi Electric installed a 750 kWp PV with 300kW diesel hybrid under the New Sunshine Project of the Ministry of International Trade and Industry. It was not connected to the island’s mainland grid and provided power to 250 households (Asaoka and Sakata, 1997). The island has maintained its active role in introducing renewables and has introduced several wind turbines and a large-scale PV facility. Efforts are also being channeled to use sugarcane to produce ethanol for the transport fleet through the Miyakojima Bio-Ecosystem Research Centre (Matsumoto and Sano, 2011; Ueno, 2008). It aims to reduce 30-40% of GHG emissions by 2030 (compared to 2003 levels) (Japan External Trade Organization, n.d.).

ACCESS:
The island is part of the Southern Archipelago of Japan and lies 300km southwest of Okinawa. There is an airport in the island with daily flights from mainland Japan (50 minutes to Okinawa Island). The only ferries operating are within the Miyako Islands.

CLIMATE:
The climate is subtropical. The average temperature is 23°C, which can drop to less than 5°C in December, January and February, but is warm for most months of the year.

MAIN REGIONAL ECONOMIC ACTIVITIES:
The tourism industry has approximately 400,000 visitors per year, and the island has robust farming (mainly sugarcane, tobacco, and mango), fishing (mozuku seaweed, prawn farming, skipjack pole-and-line fishing) and other commercial activities.

TYPES OF ENERGY NEEDS BY SECTOR:
Residential (heating, washing machines, among other major appliances) with large demand for tourism and commercial activities. There are approximately 20 thousand vehicles in the island running on fossil fuels.
PROJECT DESCRIPTION:
After the successful experience with the 750kWp PV/diesel hybrid installed almost 20 years ago, Miyakojima has continued its efforts to introduce renewable energy sources. More recently 4.2MW of wind turbines have been installed in two different sites (Karimata Area 2.4MW and Fukuzato, Bora Area 1.8MW), and further installations are being planned. Furthermore, in 2008 Miyakojima City released a “Declaration of Eco Island Miyakojima” to showcase their environmental concerns and intentions. This led the national government to develop the Miyako Island Mega Solar Demonstration Research Facility (MIMSDRF) as part of their Demonstration Project on the Introduction of New Energy Sources for Independent Systems in Remote Islands. The MIMSDRF was installed in October 2010 as a research and development project to test smart grid technologies, understand impacts when sizable PV facilities are installed, research power system stabilization measures and operation of PV and storage. The installed system is composed of 4MWp of PV (comprised of a 3MWp solar farm and 1MWp total consumer side PV) and a 4MW NaS grid-stabilization battery system and is expected to provide around 8% of the electricity needs of the island with an expected emissions reduction of 4000 tons of CO$_2$ (Datta et al., 2011). In addition, 25 of the households with 4kWp of the consumer side PV each have 8kWh of Li-Ion battery storage (200kWh total Li-Ion storage).

PROJECT OWNERSHIP:
The project is owned by the Okinawa Electricity Power Company (OEPCo).

INSTITUTIONAL FRAMEWORK / SUPPORT:
OEPCo is the main generator, transmitter and distributor of electricity in the Okinawa Prefecture. In 2001 OEPCo created the Remote Islands Operations Division to manage and operate systems in the 11 remote islands of the prefecture; in 2003 it was converted to the Remote Islands Company (RIC). The RIC has operated at a loss for its 10 years of operation, and losses continues to increase due to rising oil prices; in 2010 revenues for the RIC were only 14.5 billion yen (145 million euro) while expenditures reached almost 21 billion yen (210 million euro) (Okinawa Electric Power Company, 2011). The Mega-Solar project is managed by OEPCo.

PROJECT INSTALLER:
The project was installed by Toshiba in coordination with OEPCo.

LOAD DEMAND AND GROWTH:
Power demand is 50MW. The area has had a population decline, but there has been an increase in transient population and tourism, both of which have maintained the need for new energy sources.

GRID GENERATION SOURCES:
The power system in Miyako Island is composed of 4MWp of PV (a 3MWp mega solar power plant and 1MWp consumer side PV power generation facilities) (Toshiba, 2011), 4.2 MW of wind installed in two different locations, two diesel power stations with 19MW and 40MW capacity, and a gas turbine station with 15MW capacity. The system includes 4MW of NaS battery storage on the grid, and 200kWh of Li-ion storage on the consumer-side (i.e. “behind the meter”).

TARRIF STRUCTURE:

---

The average tariff rate for remote islands of the Okinawa prefecture is approximately 21yen/kWh (0.21 euro/kWh).66

PROJECT FINANCING:
The project in Miyako has been financed with subsidies for research as a demonstrative project from the Ministry of Economy, Trade and Industry (METI) of Japan. It is the largest among demonstration projects in Japan, Demonstrative Project of Renewable Energy on Remote Islands with a Small Independent Grid. Total project costs reached 6 billion yen (approximately 60 million euro).

PROJECT O&M:
Information is confidential as well as details on monetary savings achieved with new installation.

TRANSPORTATION DETAILS:
There are approximately 20,000 vehicles in the island running on fossil fuels (IEA, 2008). A demonstrative project was commenced in 2008 to introduce an E3 ethanol-petroleum blend to all vehicles (Matsumoto and Sano, 2011). The ethanol is primarily produced with sugarcane grown in the island.

CURRENT STATUS OF PROJECT AND NEXT STEPS:
The project has been effectively operating since October 2010. The power output and frequency fluctuation of PV with the NAS battery was tested in 2011, were output power can fluctuate up to 3MW within minutes depending on weather conditions, by using the NAS battery system this effect on the grid has been minimized according to Toshiba Power Company. Further testing and analysis continues to be carried out to examine power fluctuations and possible counter-measures.

Figure 19: Overhead photo of the PV array on Miyako Island. Source: Toshiba

---

66 Estimated from revenue and electricity generation from the RIC presented in: Okinawa Electric Power Company (2011)
### LESSONS LEARNED

<table>
<thead>
<tr>
<th><strong>TECHNICAL</strong></th>
<th><strong>Lessons</strong></th>
<th><strong>Details</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proper installation of PV panels considering climatic risks.</strong></td>
<td></td>
<td>Panels have been installed with a tilt of only 5 degrees due to limited space and to reduce damage by typhoons (Hachidai Ito et al, 2011)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>SOCIO-ECONOMIC</strong></th>
<th><strong>Lessons</strong></th>
<th><strong>Details</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Promotion of site to benefit local economy</strong></td>
<td>A number of the renewable projects (including the 3MW solar project and Sadefune Wind Turbine farm) were installed along road which hosts the annual All Japan Triathlon Miyakojima race. This has helped promote tourism that can contribute to the local economy (Hachidai Ito et al, 2011)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>INSTITUTIONAL</strong></th>
<th><strong>Lessons</strong></th>
<th><strong>Details</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Use of remote areas to pilot new technologies.</strong></td>
<td></td>
<td>This demonstration project was installed in the remote Miyako Island to test the performance of various renewable and renewable integration technologies. (Hachidai Ito et al, 2011).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>ENVIRONMENTAL</strong></th>
<th><strong>Lessons</strong></th>
<th><strong>Details</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduce environmental impact of installations</strong></td>
<td>PV panels were installed on hills constructed from limestone excavated during the site preparation works in order to blend in seamlessly with scenery (Hachidai Ito et al, 2011)</td>
<td></td>
</tr>
</tbody>
</table>

**ADDITIONAL SOURCES:** (Institute for Energy Economics Japan, 2009; Kem, 2011; Okinawa Electric Power Company, 2010)
REGION BACKGROUND:
Reunion is a large remote island located in the southern Indian Ocean, approximately 700km off the east coast of Madagascar, at 21 degrees of latitude South. The island is approximately 63km long by 45km wide in diameter, with a total surface area of roughly 2,500km². In 2010, it had a population of just over 833,000 inhabitants. Reunion remains an overseas department of France, and continues to rely on France for administrative, fiscal, technological and economic support. Like Saint-Pierre et Miquelon, Guadeloupe, and a host of other French departments, it remains part of the French Republic.

ACCESS:
Access to Reunion is either by private boat, by ferry, or by air. However, due to its remote location in the south Indian Ocean, most visitors arrive by air.

CLIMATE:
Reunion’s climate is warm and tropical and Temperature is relatively stable due to the surrounding Indian Ocean, ranging from 15° to 35°C. Solar insolation in Reunion is 5.7kWh/m2/day on average, which compares with Kauai in Hawaii (Helm and Burman, 2010). Reunion is famous for having been the region on earth with the largest recorded rainfall in a 24-hour period on the planet on March 15th 1952, at 1.87 meters. While precipitation varies widely between the coast and the interior, ranging from 636mm/year to 3634mm/year, its comparatively high rainfall combined with a number of mountains makes it an attractive place for small-scale hydro systems.

MAIN REGIONAL ECONOMIC ACTIVITIES:
While Reunion’s largest export has traditionally been raw sugar, tourism is now the primary industry. Also, in recent years the prioritization of renewable energy technologies and demonstration projects has created a number of offshoots in the green technology sector. For instance, approximately 70% of components for solar hot water systems are manufactured locally, providing a number of jobs for local citizens and residents. Total GDP in 2007 was (USD) $18.7 Billion, resulting in a per capita GDP of (USD) $23,501.

TYPES OF ENERGY NEEDS BY SECTOR:
Reunion’s total energy needs in 2008 are estimated at just over 900 kilotons of oil equivalent (ktoe), of which 70% is attributed to transportation, and 30% to electricity and thermal needs. The single largest source of transportation-related energy use is attributed to ground transport at 71%, with a further 27% by air, and 2% by sea. Businesses and local authorities use approximately 50% of total electricity generation while private customers use a further 35%, and the remainder is used by industry.
PROJECT DESCRIPTION:

There are a host of different renewable energy projects and initiatives taking place concurrently in Reunion. Many of these initiatives are occurring under the GERRI project (Green Energy Revolution Reunion Island), which is a product of cooperation between the French government, the Regional Energy Agency of Reunion (ARER), the local government, as well as local citizens and businesses. This initiative aims to make Reunion a world-leader in the full-scale adoption and integration of green energy technologies by 2030. It includes a remarkable spectrum of projects ranging from electricity generation, energy efficiency, solar hot water, wave power, wind, solar PV, ocean thermal, run-of-river hydro, electric vehicles, as well as biogas, bagasse, and algal biofuel resources, among others.

In addition to the GERRI project, a 4-year initiative called ‘Millener’ has been launched in 2010 that makes use of innovative storage and load management technologies. It aims to link up 1,000 electricity consumers with bi-directional meters that connect them to a central grid operator to control and monitor 500 solar PV units, as well as a number of large domestic appliances. In addition, 500 users will be equipped with lithium-ion storage batteries, which will be controlled and dispatched remotely in the aim of boosting grid stability, and improving the integration of solar PV on the grid.

Underpinning all of these initiatives, Reunion has established an interim goal of meeting 50% of electrical needs with renewables by 2020, and a longer-term goal of supplying 100% of Reunion’s energy needs with a diverse mix of local resources, storage, and demand side technologies by 2030. A key part of this includes a strong focus on electric vehicles, and a scale-up of the infrastructure for charging stations throughout the island is currently underway.

The following list provides a snapshot of some of the current projects that are underway:

- 200MW of PV installed on rooftops as of 2010, including two large-scale (13.5MW and 10MW) projects, parking lot parasols, etc.;
- 10MW of wind power;
- 8 hydro power plants (two larger ones), including a 78MW system that makes use of four, large (25,000 m$^3$) purpose-built water storage tanks to improve dispatchability;
- 20MW ocean thermal project (2009);
- Sea Water Air Conditioning (SWAC) project, drawing on cooler sub-surface waters to cool coastal buildings and residences (launching in 2012);
- Two innovative wave-power demonstration projects (one 30MW Pelamis project), supported by ADEME (Agence de l’Environnement et de la Maitrise de l’Energie) and Reunion;
- A grid-scale sodium-sulfur battery storage project comprised of several 1MWp units; led by EDF with assistance from ADEME and Reunion;
- 1/3 of homes have residential hot water heaters (approximately 100,000), featuring the highest solar thermal concentration in the EU, and second-highest worldwide;
- An algae project that produces 50,000 tons of biofuels per year, in conjunction with the Group Caillé.

Taken together, these initiatives and demonstration projects show a broad-based commitment to renewable energy, and toward an increasing penetration of RE in the overall energy and electricity mix. The scale of the island combined with the direct and indirect support of the French government have enabled Reunion to undertake this ambitious sustainable energy plan, and transition to a 100% renewable energy system.
PROJECT OWNERSHIP:
Due to the number of projects occurring on Reunion, this section will simply aim to provide a brief overview of the ownership structure of a few key initiatives. Note that many initiatives on the island are early-stage demonstration projects, and have benefited from both direct and indirect government support at various stages of project development, including financing. Many of the rooftop solar PV projects are privately owned, and financed under the country’s feed-in tariff, while a number of demonstration projects are either owned private by companies, or by government. As a result, most of the projects have drawn on expertise from a wide range of different companies, small and large, domestic and international. The list below highlights a few examples:

- The 10MW solar PV project installed at Reunion’s penitentiary is owned and overseen by the AKUO group, which won a bid to build the project.
- The electric vehicle project is supported jointly by Renault, EDF, Total, Group Bernard Hayot, GE Financial, with assistance from the French government.
- The large ocean thermal energy project has been undertaken by ARER, in conjunction with ADEME, the French energy research institute.
- The Millener project, consisting of deploying PV systems in conjunction with distributed storage capacity, has included participation from EDF, SAFT, Schneider Electric, Tenesol, BPL Global, among others.

INSTITUTIONAL FRAMEWORK / SUPPORT:
As an overseas department, Reunion is governed by the same laws and policies found in mainland France, and it is also subject to many principles and regulations found at the European Union (EU) level. As a result, RE projects on the island benefit from France’s feed-in tariff policy, enabling independent producers to sell power to the grid. In fact, the overseas departments receive a preferential tariff for electricity sales, one that is slightly higher than the one offered to mainland projects. This is designed to account for the higher risks and costs of remote area projects, and as recognition of the added value of deploying RETs in remote settings. The FIT policy has been a major driver behind the rapid increase in solar PV installations on the island, which already exceeds 30% on the sunniest days. One of the consequences of this high penetration of PV is that projects are sometimes curtailed in order to manage supply and demand on the grid. In fact, France has adopted a rule that limits the instantaneous share of intermittent renewables to 30%, with a particular focus on solar PV, in order to maintain grid stability.

Also, France has allocated significant administrative, financial, as well as research and development (R&D) support to Reunion in order to turn it into a testing ground for innovative technologies. This includes cooperation with its research facilities such as ADEME, as well as a close collaboration with partially state-owned firms such as EDF. This technical and operational support has been instrumental to making the sheer number and scope of projects on the island possible.

PROJECT INSTALLER:
In light of the sheer number of projects taking place on the island, it is impossible to provide a thorough examination of the installers in each case. A few examples include one of its ocean thermal projects, installed by DCNS. In the case of the large PV system installed on the grounds surrounding the penitentiary, the project was installed by the AKUO group. Other major partners include EDF, BPL Global, Group Caillé, among others.

LOAD DEMAND AND GROWTH:
With a population of 800,000 and a significant tourism industry in 2008, Reunion’s annual load totaled 2,546 GWh, 60% fossil fuel-based, and approximately 40% renewable energy powered. Load growth has been quite rapid with the growth of the tourism industry, and has been sustained at 4-5% per year since 2000. Combined with its efforts to achieve a high-level of RE penetration, Reunion is in need of an expanded generation base, both to phase out existing fossil generation and to meet incremental load growth. However, demand side efforts are helping moderate electricity demand growth, through projects like the sea water air conditioning (SWAC) system, and the deployment of solar thermal collectors, and smart grid technologies.

GRID GENERATION SOURCES:
The following chart shows the electricity mix in Reunion in 2008:

![Reunion Generation Mix (2008)](image)

Note: the share of solar and other RE technologies has grown significantly since then; solar alone now supplies well over 5% of annual demand.

By 2010, RE sources supplied 37% of electricity demand and that share continues to grow as new projects are connected to the grid. Interestingly, the theoretical potential of certain resources such as wave power is phenomenal, estimated at over 2,000TWh/yr for wave power alone – this represents half the total electricity consumption of the United States.

PROJECT FINANCING:
The majority of projects on Reunion are based on cooperation between government and the private sector, with contributions coming from different levels of government. In light of the sheer number of projects taking place on Reunion, it is impossible to provide a detailed, project-by-project breakdown of the financing that enabled them to be built. However, the active engagement of both the government, directly as well as through its research institutes like ADEME, as well as through utilities such as EDF, have helped make the wide range of initiatives possible. Most projects include some shared contribution of public and private capital.
PROJECT O&M:
For one of the ocean thermal energy projects, O&M services are shared between ARER and partners from Reunion’s local government. A tidal powered project (Solon) has been launched by Atlantis-Macquarie, a firm operating in this sector, while one of the wave-powered projects has been undertaken through cooperation between EDF, with support from ADEME and the Reunion energy agency (ARER). The electric vehicle initiative is undertaken in collaboration with Renault, the French automaker, while the French government has directly supported much of the charging infrastructure. In an innovative approach, the PV project on Reunion’s jail is drawing on the maintenance efforts of inmates, as part of a rehabilitation initiative, to take care of the solar PV farm.

CURRENT STATUS OF PROJECT AND NEXT STEPS:
Based on the number of projects underway, it is clear that Reunion Island is moving rapidly toward a more sustainable energy future. It has adopted an integrated, multi-sectoral approach, and has engaged many different levels of government in collaboration with the private sector and leading government research institutes to pilot dozens of innovative renewable energy projects. Several new initiatives are planned, and the island as a whole is rapidly becoming a full-blown laboratory for the research, development and demonstration of clean energy technologies that will be applicable to remote areas and islands worldwide, as well as to mainland grids seeking to increase the level of RE penetration in their electricity, heating/cooling, and transportation systems.

ADDITIONAL SOURCES:  (Fabrégat, 2010; Grenelle de l’Environnement à la Reunion - Réussir l’Innovation (GERRI), 2008, 2010; WE’REUNION, 2010)
## LESSONS LEARNED

### TECHNICAL

The use of innovative storage, metering, and demand side management strategies becomes increasingly important as a jurisdiction aims for higher levels of RE penetration. A number of storage projects are underway in Reunion, from electric vehicles to hydro storage to MW-scale NAS batteries as well as residential-scale Li-ion units. Advanced metering systems have also helped control load fluctuations.

Load growth needs to be carefully factored in, particularly on islands experiencing rapid growth in tourism. Indeed, adopting an ambitious RE strategy can contribute to increasing tourism, which tends to increase load growth. This should be factored in for islands developing flagship initiatives.

### SOCIO-ECONOMIC

Cooperation between all project partners and members of the society, including local residents, is the key to success for ambitious renewable energy strategies. Reunion’s goal of becoming almost entirely self-sufficient in energy needs has galvanized many citizens, and helped foster greater cooperation and collaboration.

Having local equipment providers and installers can increase community support, and help enhance economic benefits. Reunion has a number of manufacturers producing solar hot water systems, and a burgeoning market in RET installers.

### INSTITUTIONAL

The extension of France’s feed-in tariff policy to island regions has played a significant role in encouraging solar PV development in particular in remote departments. This shows the role that national policies can play in supporting RE deployment in remote regions.

Technical and institutional support from existing energy departments, or research agencies, can provide valuable help in planning and implementation. At many stages, French agencies such as ADEME have provided invaluable technical and institutional assistance. Participation from major utilities like EDF has also contributed positively by supplying expertise.

Integration of renewable energy technologies should be accompanied by energy efficiency regulations and incentives. Rebates for high-efficiency refrigerators and other equipment, or enhanced efficiency standards on products sold in remote areas, can help improve electrical system operation.

### FINANCIAL

Government leadership can significantly increase the willingness of the private sector to step in, and invest in innovative RD&D projects. Reunion has benefited from the active engagement of government at many levels in providing direct and indirect support for projects.

Partnerships can facilitate access to funds. The many projects on Reunion occurring in parallel were successful in part due to the financial contributions from many different actors, including government, the private sector, individual citizens, and non-governmental agencies.

### ENVIRONMENTAL

The project increased awareness of environmental issues on the island, and has triggered other environmental initiatives. Residents on Reunion are increasingly engaged in the renewable energy transition, a fact that has been made even more important with the increase in the use of electric vehicles on the island. This provides many benefits, including decreased carbon emissions, reduced likelihood of oil spills, and cleaner air for local residents.
SCOTT BASE & MCMURDO STATION, ANTARCTICA
REMOTE RESEARCH STATION

WIND/ DIESEL HYBRID PROJECT

REGION BACKGROUND:
Antarctica New Zealand (AntNZ) owns and operates Scott Base and the U.S. National Science Foundation (NSF) owns and operates McMurdo Station as part of the U.S. Antarctic Program. The two stations are located at the southern tip of Hut Point Peninsula on Ross Island, Antarctica. The island is the southernmost island reachable by sea and was discovered in 1841.

ACCESS:
Access is limited to 3 or 4 months of the year, between November and February. Because of this, the wind farm relied on only one supply ship a year to bring everything needed to the area. Site works were performed during the short summer season (beginning of November to end of February), where there is 24-hour daylight. Transportation outside the bases is limited to petroleum power vehicles.

CLIMATE:
The bases are in the Antarctic region. The average annual -17°C temperature. In August the average temperature is -26°C, and in January the average temperature is -2°C.

MAIN REGIONAL ECONOMIC ACTIVITIES:
Research is the exclusive economic activity.

TYPES OF ENERGY NEEDS BY SECTOR:
Energy is required for research along with the residential loads for on-site researchers.

PROJECT DESCRIPTION:
This project is a multi-stage project. Phase 1 was designed to be proof-of-concept, with later stages displacing up to 50% of the diesel production. The three wind turbines and flywheel storage system installed as part of Phase 1 provide 11% of the power needs of the island. Scoping studies for the project began in 2005, on-site testing in 2007, with construction commencing in November 2008, and commissioning in February 2010. Later phases may install more than 20 wind turbines on the island.

PROJECT OWNERSHIP:
The AntNZ owns the project on behalf of international research interests in Antarctica. AntNZ has established a memorandum of understanding with New Zealand state-owned retailer/generator/developer Meridian Energy Ltd to provide on-going support and personnel to maintain the project.

INSTITUTIONAL FRAMEWORK/SUPPORT:
Meridian is New Zealand’s largest electricity generator, and is wholly owned by the government of New Zealand. Meridian also operates domestic retail electricity and develops renewable energy projects worldwide. Meridian was approached by AntNZ to develop the project. The Antarctic Treaty principles of environmental protection and international cooperation for research were incorporated in the project development; the project shares electricity with both the US and New Zealand bases.
PROJECT INSTALLER:
Meridian Energy is the primary contractor, with key support from Antarctica New Zealand and the US Antarctic Program. The on-site work was undertaken by a team of 6 to 15 people during construction over two summer seasons (from November to February). The project was designed to minimize disruption to research; each worker used facilities that could have been used by a research scientist’s place, and overhead costs were $1,000 per person per night. The construction team typically worked 10-hour days, six days a week to expedite installation during the available install window. Powercorp and Vergnet both provided equipment expertise to facilitate project installation.

LOAD DEMAND AND GROWTH:
Scott Base houses up to 86 people and generates an average electricity load of around 150kW. American McMurdo Station is the largest of all the Antarctic research stations, with capacity for 1,250 people and an average electricity load of 1.6MW (1,600 kW). Load growth is shared across the two bases and is dictated by research needs.

GRID GENERATION SOURCES:
The system is composed of 3 x 330kW Enercon E33 WEC wind turbines designed for low-temperature operation and do not have a gearbox or oil, and a 500kW Powercorp PowerStore flywheel to smooth wind farm output. The wind farm is interconnected with a diesel microgrid owned by American McMurdo Base. The Wind Farm operates on a 60Hz frequency since the majority of production supplies McMurdo. The 60Hz load is converted to 50Hz to supply New Zealand’s Scott Base. The existing diesels are never turned off.

TARIFF STRUCTURE:
N/A

PROJECT FINANCING:
The installation cost about $7.4 million dollars, contributed in large part by New Zealand. The project is part of New Zealand’s contribution to a long-standing joint logistics pool for funding research in Antarctica.

PROJECT O&M:
Meridian and AntNZ signed a memorandum of understanding to allow for on-going sharing of personnel and resources to support the project.

CURRENT STATUS OF PROJECT AND NEXT STEPS:
The project is fully operational, with additional phases under consideration. Solar is being considered since most researchers visit in the summer when there is 24-hour sun.
Figure 20: Aircraft delivering PowerCorp Frequency Converter for Ross Island.

<table>
<thead>
<tr>
<th>LESSONS LEARNED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TECHNICAL</strong></td>
</tr>
<tr>
<td>Access restrictions should be considered when selecting appropriate designs. The machines are designed for low-temperature operation and do not have a gearbox or oil, which reduce maintenance needs. Project engineers planned a year in advance to ensure that all components were ready for the supply ships to deliver when Ross Island was accessible.</td>
</tr>
<tr>
<td><strong>SOCIO-ECONOMIC</strong></td>
</tr>
<tr>
<td>Residents with extensive local knowledge should be consulted and incorporated into the process. As there are no indigenous residents, a veteran engineer with over 25-years’ experience in Antarctica was consulted to share his inside knowledge, including tricks to use the cold weather to make ice-based concrete replacements.</td>
</tr>
<tr>
<td><strong>INSTITUTIONAL</strong></td>
</tr>
<tr>
<td>Remote areas that have cooperation between all major stakeholders will lead to good project outcomes, through project installation support and integration to minimize excess equipment. The wind farm was installed with full support from AntNZ and the NSF.</td>
</tr>
<tr>
<td><strong>FINANCIAL</strong></td>
</tr>
<tr>
<td>RETs and hybrid systems can be used in remote areas to reduce operational cost and reduce the logistical burden of supplying diesel fuel. The cost and logistical savings will benefits and reduce the cost of research.</td>
</tr>
<tr>
<td><strong>ENVIRONMENT</strong></td>
</tr>
<tr>
<td>RETs are the preferred technology when conducting research in sensitive environments. The wind turbines on Ross Island will reduce the likelihood of fuel spills.</td>
</tr>
</tbody>
</table>
6 AKKAN, MOROCCO
DEVELOPING REMOTE AREAS

PV HYBRID MICROGRID | 35 HOUSEHOLDS

REGION BACKGROUND:
Akkan is an isolated hamlet (douar) in the province of Chefchaouen with 35 households, a school and a mosque. It had no electricity access. Access to energy services was limited to candles, kerosene, wood and batteries.

ACCESS:
Road access was opened during project execution. However, there are no formal transportation services in the community. Residents travel either by foot or mules. There are a few tractors used for agricultural activities.

CLIMATE:
The climate is Mediterranean. It is hot and dry from April to October, while cool with some rain from November to March.

MAIN REGIONAL ECONOMIC ACTIVITIES:
Main regional economic activities include agriculture and cattle grazing.

TYPES OF ENERGY NEEDS BY SECTOR:
Akkan has basic residential energy needs (lighting, radios, TVs) as well as some light commercial needs.

PROJECT DESCRIPTION:
This project was implemented as a pilot demonstration in 2005 by local consultants in the community. By 2006 the construction began on a project to provide electricity to 30 households, a school, the mosque, a communal house and public lighting. Energy daily allowance (EDA) meters were used that limit electricity consumption. The project also included installing road access to the community.

PROJECT OWNERSHIP:
The project is jointly owned by the Municipality of Chefchaouen (MoC) and a local community organization, Local Association of Akkan (LAA). This partnership was established to prevent either party from selling the assets without the other’s permission.

INSTITUTIONAL FRAMEWORK/SUPPORT:
The Moroccan Public Utility (MPU) has jurisdiction on electricity services and access throughout the country. The MPU’s 10-year electrification plan included the village of Akkan, but did not include plans for interconnection. In response to this, the MoC applied for approval from the MPU to commission the PV project for the community. The result is that the town has approval to manage the local electricity grid independent of the municipality. Each user has an agreed contract for service supply.
PROJECT INSTALLER:
Engineering firm Trama Tecno Ambiental (TTA) was in charge of project coordination and design together with the Instituto Catalán de Energía (ICAEN), the Instituto de Promoción y Apoyo al Desarrollo (IPADE) and the local NGO Asociación de Desarrollo Local de Chefchaouen (ADL). Local contractors were used for the installation.

LOAD DEMAND AND GROWTH:
The initial energy needs assessment determined that each user required 465kWh/year. EDA contracts were signed by consumers to formalize this limit. Measured data from 2007 and 2009 indicates that total electricity consumption has remained approximately 5,550kWh/yr. In 2011, one house was added to the town, but there has been no considerable growth in electricity demand. The diesel genset has not been used in 2011.

GRID GENERATION SOURCES:
The microgrid is composed of a 5.6 kWp PV installation, a 72 kWh battery bank, a 6kW battery charge controller, a 7.2kW inverter/rectifier and an 8.2kW back-up diesel genset. EDA meters that limit consumption were installed at all electrical access points to manage demand. The generation building contains most of the system components, with the PV array on the rooftop. A generation management unit was installed that provides information on current generation and energy availability. The interface provides local technicians with the system’s operation and current status, along with storing the long-term information on the system. 95% of the electricity consumed is expected to come from renewable sources.

TARIFF STRUCTURE:
Each user has a contract for service and supply. The tariff structure agreed upon by the community was to set flat monthly rates for all users who pre-contracted the service before installation. The tariff has two levels depending on allowed energy consumption. 23 users opted for an 8.4kWh/month electricity limit, while 3 users chose a larger, more expensive 16.7kWh/month limit. The municipality pays for electricity for public lighting, the mosque and school; however, the LAA was unable to charge this since it did not have the appropriate authority.

PROJECT FINANCING:
80% of the pilot project was financed with funds from the Spanish Cooperation Agency (AECID). The remaining 20% came from the local community. The MoC provided in-kind contribution of machinery to improve road access to Akkan.
PROJECT O&M:
The O&M costs are paid with the tariffs collected from all users and so far has been sustainable. The LAA is in charge of operating and managing the system, with basic maintenance provided by the community. However, an external qualified technician is contracted for specific preventive and corrective maintenance activities beyond the capacity of the community. A fund has been created for battery replacement.

CURRENT STATUS OF PROJECT AND NEXT STEPS:
There have been no major system failures. Users report high satisfaction with the system, but have begun to request greater electricity availability. Some meters have been damaged and there are no spare parts available, so households are connecting directly which raises concerns of future operational challenges and increased electrical consumption beyond the agreed limits.
Figure 21: Images of Akkan. Source: Trama TecnoAmbiental S.L.
<table>
<thead>
<tr>
<th>LESSONS LEARNED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TECHNICAL</strong></td>
</tr>
<tr>
<td>The use of energy daily allowance meters helps to prevent major system failures. There has been a limited demand growth and the present installation has been able to couple with needs adequately. Planning process for adding users to the microgrid has been very controlled. <strong>Particularly in developing areas, system upgrades will be necessary as users increase their reliance on the electrical system and consumption grows.</strong> There was no electrical access before the project, but electrical demand has grown quickly in Akkan. The residents are already asking for more electrical access after 5 years. <strong>Well-designed user and operator interfaces improve overall system performance.</strong> The EDA meters and generation system management unit have facilitated the users’ and technician’s interaction, respectively, with the system. These interfaces are an important part of the preventive maintenance plan.</td>
</tr>
<tr>
<td><strong>SOCI-ECONOMIC</strong></td>
</tr>
<tr>
<td>Using a local installer will build local capacity while ensuring proper maintenance and technician availability. A local technician was contracted for design and installation. The local technician has since been able to perform many maintenance tasks. <strong>Access satisfaction.</strong> A survey carried out a year after the installation showed that 75% of users were satisfied with service. The most valued commodity was having light at night, 60%. The main complaints were the possibility to have more electricity available – 45%.</td>
</tr>
<tr>
<td><strong>INSTITUTIONAL</strong></td>
</tr>
<tr>
<td>Community sustained projects are feasible if implemented properly. The community has been capable of maintaining the system operating for 5 years without major issues, even though the national government and utility have supported but not been heavily involved in the process.</td>
</tr>
<tr>
<td><strong>FINANCIAL</strong></td>
</tr>
<tr>
<td>Cooperation projects should seek for long-term sustainable operation of systems. Local involvement and tariff system implemented has enabled the project to continue operating. <strong>International and public funds still play an important role in remote areas of developing countries for providing access to electricity.</strong> This project would not have been feasible without international support. <strong>The creation of an O&amp;M fund for major longer-term investments can create challenges.</strong> By 2011, the community had used half of the collected funds to refurbish the local road. This is an important local infrastructure project but may compromise future battery replacements and the long term viability of the electrical system.</td>
</tr>
</tbody>
</table>
CASE STUDY INTERVIEWS

- Abdelmoghit, Hasnaoui, Coordinateur général d'ADL-Chefchaouen
- Fernández, Miguel Angel, Project Manager, IDOM Ingeniería
- Fyffe, Maggie – Secretary and Key contact Isle of Eigg Heritage Trust
- Piernavieja, Gonzalo, Director of Technological Research and Development Division, ITC
- Axel Strang, Ministère de l’Écologie, de l’Énergie, du Développement Durable et de la Mer in France
- Suárez, Salvador, Chief of the Renewable Energy Department, ITC
- Thomsen, Jogvan, SEV
APPENDIX B: IEA-RETD COUNTRY PROFILES

A baseline survey of renewable energy development in remote areas in the IEA-RETD countries was conducted (the “countries in scope”). The goal of the baseline survey was to assess the availability of data on remote areas and identify existing energy policies for remote communities.

Since starting the project in August 2011, 15 key stakeholders related to energy policy and remote communities in the member countries were interviewed. The data requests to each country to focus on four primary questions:

1. Whether/how does your country define what a remote area is?
2. Where are the remote areas in your country?
3. Are there specific programs or policies supporting energy development in those areas?
4. Are there relevant initiatives or pilot projects that showcase the country’s work with energy in remote communities?

The responses from each interview and data request varied from country to country in their detail and content. Countries that have a considerable portion of their land mass in harsh climates or terrain, such as Canada and Norway, have made extensive progress to understand where remote communities exist and have proactive policies in place that address energy concerns for the residents of these communities. Other IEA-RETD countries (e.g. Germany) have few remote areas and have therefore not launched coordinated energy policies for remote communities. There was also a question of what constituted the jurisdictions “in scope” – particularly for countries that maintain overseas territories. France includes its overseas territories as part of the “mainland” nation, and has implemented national programs to manage energy prices and explore options to reduce generation costs. For the Netherlands overseas (Caribbean) islands there is a complex legal/constitutional situation because the former Netherlands Antilles (6 islands) no longer exist as of 2010. However, the Dutch government still helps the BES islands (Bonaire, St. Eustatius and Saba) with their energy policy, although formally they are independent to decide on their own. Other states, such as Denmark and the UK, have looser relationships with their more autonomous overseas jurisdictions and adopt a more hands off approach to energy policy in remote areas -- deferring instead to local governments. Japan considers all 6,000 of its islands to be remote, and is taking steps to manage energy costs and availability for its remote communities on the 400+ inhabited islands.

The sections below profile each of the IEA-RETD countries’ experience with policies for energy remote areas. Each profile is structured in a manner that corresponds to the four basic questions detailed above. A key lesson that has emerged through the research process is that there does not seem to be detailed information readily available on remote areas from most of the countries in scope – either in the published literature or from the governments themselves. Building a standard database of information and case studies among the IEA-RETD countries would be a useful exercise for future work under REMOTE.
<table>
<thead>
<tr>
<th>Categories</th>
<th>Key Contacts</th>
<th>Remote Areas Considered in Study</th>
<th>Population Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canada</strong></td>
<td>1,5 Galina Obolenskaia, Natural Resources Canada Amy Keuhl, AANDC</td>
<td>293 communities (171 Aboriginal)</td>
<td>195,335</td>
</tr>
<tr>
<td><strong>Denmark</strong></td>
<td>1,2,5 Ina Jakobsen, Nordic Energy Denmark Inger Strand Karni, Nordic Energy Denmark Margaret Sorensen, Nordic Working Group</td>
<td>Greenland and the Faroe Islands</td>
<td>105,882</td>
</tr>
<tr>
<td><strong>France</strong></td>
<td>2,3,4,5 Axel Strang, DCEC France</td>
<td>Overseas departments and territories, e.g. Reunion island, St. Pierre et Miquelon, and New Caledonia</td>
<td>2,685,705</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td>5 Bruno Burger, Fraunhofer</td>
<td>Remote research stations</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Ireland</strong></td>
<td>5 Matthew Kennedy, SEAI</td>
<td>Remote research stations</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td>2,5 Kaoru Yamaguchi, IEE Japan</td>
<td>6847 islands, 430 of which are inhabited</td>
<td>435,000</td>
</tr>
<tr>
<td><strong>Netherlands</strong></td>
<td>3,4 Neeltje Muselaers, Ministry of Economic Affairs Bob Schulte, Ecofys</td>
<td>Constituent countries and special municipalities, e.g. Aruba, Curacao, St. Maarten, Bonaire, Saint Eustatius, and Saba</td>
<td>175,653</td>
</tr>
<tr>
<td><strong>Norway</strong></td>
<td>1,2,5 Ingrid Slungaard Myklebust, Enova</td>
<td>Islands and remote inland communities, e.g. Finnmark County and Troms County</td>
<td>341,003</td>
</tr>
<tr>
<td><strong>United Kingdom</strong></td>
<td>1,2,3,5 Paul Chambers, DECC UK Paul Irving, Foreign and Commonwealth Office Amie Fulton, Rural Development Council</td>
<td>Northern Scotland and British Overseas Territories (BOT)</td>
<td>254,821 (BOT only)</td>
</tr>
</tbody>
</table>
### Table 10: Project Team Research Results

<table>
<thead>
<tr>
<th>Country</th>
<th>Definition of Remoteness</th>
<th>Highlighted Energy Strategies for Remote Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canada</strong></td>
<td>Any community not currently connected to the North-American electrical grid nor to the piped natural gas network and is a permanent or long-term settlement with at least 10 dwellings is considered energy remote.</td>
<td>Communities in Hydro-Québec service territory pay a flat rate regardless of whether they are connected to the central grid or rely on local energy generation.</td>
</tr>
<tr>
<td><strong>Denmark</strong></td>
<td>None</td>
<td>• Greenland: Flat rate for heat. Electricity prices vary but there is a ceiling on what a utility can charge.</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>• Faroe Islands: Joint venture with DONG energy to test smart-grid technology and implement more renewable energy.</td>
</tr>
<tr>
<td><strong>France</strong></td>
<td>Areas that are not connected to the continental transmission grid</td>
<td>• Electricity rates are set across most French territories and islands to match what customers in mainland France pay.</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>• Feed-in tariffs support renewable energy projects in France’s remote regions.</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td>None</td>
<td>None identified</td>
</tr>
<tr>
<td><strong>Ireland</strong></td>
<td>None</td>
<td>None identified</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td>Communities on islands beyond the 5 main islands are considered geographically remote.</td>
<td>Electricity rates are set across all Japanese islands to match what customers on Japan’s central grid pay.</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>• The local governments mostly own the public (water, electricity) companies, with the exception of Bonaire, where the electricity production company (ecopower) is privately owned.</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>• On the BES islands (Bonaire, St. Eustatius and Saba) a special &quot;BES&quot; electricity law applies, which is far more basic than the Dutch electricity law. According to this law the local (BES) governments may perform a price policy but in practice this does not happen right now, partly because the BES constitution only functions since less than two years.</td>
</tr>
<tr>
<td><strong>Norway</strong></td>
<td>An cluster of houses with a total population of less than 200 people in which the houses are 50 meters apart or less are considered geographically communities.</td>
<td>Every household is entitled to a grid connection, and the utility must share in the interconnection cost if the residence is considered a permanent household.</td>
</tr>
<tr>
<td><strong>United Kingdom</strong></td>
<td>Scotland specifically classifies communities with less than 3,000 people and with a driving time of over 60 minutes to a settlement of 10,000 people or more to be geographically remote.</td>
<td>Scotland provides rebates for energy efficiency upgrades for rural residents.</td>
</tr>
</tbody>
</table>
OVERVIEW OF REMOTE AREAS

Out of the 9 IEA-RETD member countries that were interviewed, Canada had the most comprehensive definition of energy remoteness. Natural Resources Canada (NRCan), along with the CammetENERGY-Varennes team and Aboriginal Affairs and Northern Development Canada (AANDC), has been tracking and addressing energy concerns for over 300 remote communities since 1985. A recent survey from NRCan outlines the latest definition of a “remote” community:

The terms “off-grid community” and “remote community” are used interchangeably within the context of this report for communities that fulfill the following criteria:

1. Any community not currently connected to the North-American electrical grid nor to the piped natural gas network; and
2. Is a permanent or long-term (5 years or more) settlement with at least 10 dwellings.

The North-American electrical grid is further defined in the Canadian context as any provincial grid under the jurisdiction of the North American Electric Reliability Corporation (NERC) and including the Newfoundland and Labrador main grid but excluding all territorial grids and provincial local grids.

Applying the above definition to the 2006 census data, NRCan found that there are 195,335 people living in 293 remote communities across Canada. 28% of this population lives in three large communities – Yellowknife (18,700), Whitehorse (22,900), and the Magdalen Islands (13,180). The remaining population is distributed across British Columbia, Alberta, Manitoba, Saskatchewan, Ontario, Quebec, Newfoundland and Labrador, Yukon, Northwest Territories, and Nunavut. Prince Edward Island, New Brunswick, and Nova Scotia do not have any remote communities. Table 3 shows the breakdown of communities and population by Province. Figure 1 shows the locations of these communities on a map with respect to their distance from the national electric grid, with the green dots indicating the Aboriginal communities.
### Table 11: Population and Location of Remote Communities (NRCan, 2011)

<table>
<thead>
<tr>
<th>Province or Territory</th>
<th>Type</th>
<th># Sites</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Columbia (BC)</td>
<td></td>
<td>86</td>
<td>24,068</td>
</tr>
<tr>
<td>Alberta (AB)</td>
<td></td>
<td>2</td>
<td>533</td>
</tr>
<tr>
<td>Manitoba (MB)</td>
<td></td>
<td>7</td>
<td>3,063</td>
</tr>
<tr>
<td>Saskatchewan (SK)</td>
<td></td>
<td>1</td>
<td>57</td>
</tr>
<tr>
<td>Ontario (ON)</td>
<td></td>
<td>38</td>
<td>21,342</td>
</tr>
<tr>
<td>Quebec (QC)</td>
<td></td>
<td>44</td>
<td>34,729</td>
</tr>
<tr>
<td>Newfoundland and Labrador (NL)</td>
<td></td>
<td>29</td>
<td>10,429</td>
</tr>
<tr>
<td>Yukon (YT)</td>
<td></td>
<td>22</td>
<td>30,176</td>
</tr>
<tr>
<td>Northwest Territories (NT)</td>
<td></td>
<td>38</td>
<td>41,950</td>
</tr>
<tr>
<td>Nunavut (NU)</td>
<td></td>
<td>26</td>
<td>29,453</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td><strong>293</strong></td>
<td><strong>195,335</strong></td>
</tr>
</tbody>
</table>

### Figure 1: Location of Remote Communities (NRCan, 2011)

[Map image showing the location of remote communities in Canada, with labels for Aboriginal and Non-Aboriginal Communities.]
NRCan has completed an extensive analysis of the energy infrastructure of the 293 remote communities. While there are a few communities that have built local hydro facilities, a majority rely heavily or solely on diesel generation. According to NRCan, 251 communities have their own fossil fuel plants totaling 453.3 MW, while 46 communities rely on 11 hydro facilities with a total generating capacity of 153.1 MW.

An attempt to understand the electricity demand in each community had mixed results. NRCan was able to collect data from 194 communities, although the accuracy of this data is unknown. From this data, it was found that energy demand per capita ranged from 3.3 MWh/year in Saskatchewan to 14.4 MWh/year in Nunavut. Table 4 outlines the electricity demand per capita for the remote communities broken down by region.

Table 12: Electricity Demand Per Capita (NRCan, 2011)

<table>
<thead>
<tr>
<th>Province</th>
<th>Capacity FF (kW)</th>
<th>Capacity RE (kW)</th>
<th>Capacity Total (kW)</th>
<th>Year Reported</th>
<th>Sites Reported</th>
<th>Capacity/ Person (kW/p)</th>
<th>Demand/ Person (MWh/y/p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>1,450</td>
<td>-</td>
<td>1,450</td>
<td>NA</td>
<td>1</td>
<td>7.44</td>
<td>12.2</td>
</tr>
<tr>
<td>BC</td>
<td>68,072</td>
<td>4,328</td>
<td>72,400</td>
<td>2005</td>
<td>49</td>
<td>5.18</td>
<td>9.9</td>
</tr>
<tr>
<td>MB</td>
<td>7,175</td>
<td>-</td>
<td>7,175</td>
<td>2006</td>
<td>6</td>
<td>2.44</td>
<td>4.4</td>
</tr>
<tr>
<td>NL</td>
<td>23,598</td>
<td>600</td>
<td>24,198</td>
<td>2004</td>
<td>26</td>
<td>2.97</td>
<td>5.6</td>
</tr>
<tr>
<td>NT</td>
<td>72,919</td>
<td>50,633</td>
<td>123,552</td>
<td>2008</td>
<td>29</td>
<td>3.36</td>
<td>9.7</td>
</tr>
<tr>
<td>NU</td>
<td>50,295</td>
<td>53</td>
<td>50,348</td>
<td>2006</td>
<td>25</td>
<td>1.71</td>
<td>14.4</td>
</tr>
<tr>
<td>ON</td>
<td>25,210</td>
<td>520</td>
<td>25,730</td>
<td>2007</td>
<td>28</td>
<td>1.76</td>
<td>5.8</td>
</tr>
<tr>
<td>QC</td>
<td>37,000</td>
<td>-</td>
<td>37,000</td>
<td>2007</td>
<td>19</td>
<td>2.55</td>
<td>10.2</td>
</tr>
<tr>
<td>SK</td>
<td>350</td>
<td>-</td>
<td>350</td>
<td>NA</td>
<td>1</td>
<td>6.14</td>
<td>3.3</td>
</tr>
<tr>
<td>YT</td>
<td>41,900</td>
<td>75,810</td>
<td>117,710</td>
<td>2005</td>
<td>10</td>
<td>4.57</td>
<td>10.2</td>
</tr>
<tr>
<td>Total</td>
<td>327,969</td>
<td>131,944</td>
<td>459,913</td>
<td>194</td>
<td>3.14</td>
<td>10.1</td>
<td></td>
</tr>
</tbody>
</table>

NRCan has also studied the fuel costs and retail electricity rates in 100 remote communities that rely on diesel generation. Table 5 breaks down these costs by province.
Table 13: Fuel Costs and Retail Electricity Costs for Remote Communities using Diesel Generation (NRCan, 2011)

<table>
<thead>
<tr>
<th>Province</th>
<th>Fuel Purchased (FP) liter/yr</th>
<th>Sites with FP Reported</th>
<th>Diesel Cost to Utility $ (€) /liter</th>
<th>Last Year Reported</th>
<th>Consumer Electricity Rate (ERC) $ (€) /kWh</th>
<th>Sites with ERC Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>-</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>BC</td>
<td>3,117,100</td>
<td>15</td>
<td>$ 0.37 (€ 0.27)</td>
<td>2005</td>
<td>$ 0.37 (€ 0.27)</td>
<td>15</td>
</tr>
<tr>
<td>MB</td>
<td>-</td>
<td>NA</td>
<td>-</td>
<td>NA</td>
<td>$ 0.36 (€ 0.26)</td>
<td>4</td>
</tr>
<tr>
<td>NL</td>
<td>2,373,206</td>
<td>2</td>
<td>$ 0.34 (€ 0.25)</td>
<td>2004</td>
<td>$ 0.14 (€ 0.10)</td>
<td>5</td>
</tr>
<tr>
<td>NT</td>
<td>14,218,794</td>
<td>25</td>
<td>$ 0.46 (€ 0.34)</td>
<td>2008</td>
<td>$ 0.26 (€ 0.19)</td>
<td>34</td>
</tr>
<tr>
<td>NU</td>
<td>40,280,886</td>
<td>25</td>
<td>$ 0.51 (€ 0.37)</td>
<td>2006</td>
<td>$ 0.60 (€ 0.44)</td>
<td>25</td>
</tr>
<tr>
<td>ON</td>
<td>20,186,525</td>
<td>24</td>
<td>$ 0.80 (€ 0.59)</td>
<td>2007</td>
<td>$ 0.17 (€ 0.12)</td>
<td>8</td>
</tr>
<tr>
<td>QC</td>
<td>4,314,593</td>
<td>2</td>
<td>$ 0.38 (€ 0.28)</td>
<td>2007</td>
<td>$ 0.40 (€ 0.29)</td>
<td>19</td>
</tr>
<tr>
<td>SK</td>
<td>-</td>
<td>NA</td>
<td>-</td>
<td>NA</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>YT</td>
<td>5,391,000</td>
<td>4</td>
<td>$ 0.36 (€ 0.26)</td>
<td>2005</td>
<td>$ 0.26 (€ 0.19)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>90,232,104</td>
<td>97</td>
<td><strong>$ 0.46 (€ 0.34)</strong></td>
<td></td>
<td><strong>$ 0.32 (€ 0.23)</strong></td>
<td>111</td>
</tr>
</tbody>
</table>

Using the average consumer electricity rate from Table 5 and the average demand per person per year from Table 4, the average cost per person per year could be determined. Multiplying this average by the population of remote areas in each province from Table 3 gives us an estimated total cost per year for electricity.
Table 14: Cost per Person Per Year and Total Cost Per Year by Province

<table>
<thead>
<tr>
<th>Province</th>
<th>Cost per Person per Year $ (€) /person</th>
<th>Total Cost per Year $ (€) /year</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BC</td>
<td>$3,663.00 (€2,666.66)</td>
<td>$88,161,084 (€64,181,269)</td>
</tr>
<tr>
<td>MB</td>
<td>$1,584.00 (€1,153.15)</td>
<td>$4,851,792 (€3,532,105)</td>
</tr>
<tr>
<td>NL</td>
<td>$784.00 (€570.75)</td>
<td>$8,176,336 (€5,952,373)</td>
</tr>
<tr>
<td>NT</td>
<td>$2,522.00 (€1,836.02)</td>
<td>$105,797,900 (€77,020,871)</td>
</tr>
<tr>
<td>NU</td>
<td>$8,640.00 (€6,289.92)</td>
<td>$254,473,920 (€185,257,014)</td>
</tr>
<tr>
<td>ON</td>
<td>$986.00 (€717.81)</td>
<td>$21,043,212 (€15,319,458)</td>
</tr>
<tr>
<td>QC</td>
<td>$4,080.00 (€2,970.24)</td>
<td>$141,694,320 (€103,153,465)</td>
</tr>
<tr>
<td>SK</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>YT</td>
<td>$2,652.00 (€1,930.66)</td>
<td>$80,026,752.00 (€58,259,475)</td>
</tr>
</tbody>
</table>

Through this study, NRCan discovered that communities that are highly dependent on air transportation will pay up to twice as much for fuel than communities that have barge or road access. This disparity is reflected in the high price that Ontario pays for its fuel ($0.80/liter or €0.59/liter) as opposed to Newfoundland, which is water accessible and pays less than half the price ($0.37/liter or €0.27/liter).

NRCan also discovered that fuel price does not directly drive the price of electricity. Other considerations, such as the size and efficiency of the generators used, can have an equivalent influence on the retail price. Subsidies also play a role in determining the retail electric rate for certain remote communities.

**CURRENT ENERGY POLICY**

Subsidies to lower the cost of energy in remote communities are in place in Canada, but they vary based on province and utility provider. For example, remote communities in Hydro-Quebec territory pay the same rate as their on-grid counterparts. Other utilities in Ontario, Newfoundland, and Labrador also use the same subsidy scheme. The northern Territories such as the NWT and Nunavut receive an annual lump-sum subsidy from the federal government designed to cover a host of basic services ranging from health care, to education, to electricity provision. The Territorial governments have discretion over how this subsidy is spent, and can determine the relative proportion that is allocated to subsidize electricity prices, versus education and health services.

Also, some provinces such as British Columbia have developed production incentives that offer a preferential rate for projects that supply electricity in remote areas, where BC Hydro’s (the public utility’s) cost of service is higher.
With regard to renewable energy subsidies, the federal ecoENERGY for Aboriginal and Northern Communities Program, an initiative through Aboriginal Affairs and Northern Development Canada (AANDC), provides funding up to $250,000 (€ 178,400) for the planning of renewable energy projects and up to $100,000 for the design and construction of energy projects integrated with community buildings. Since 2007, the ecoEnergy project has provided close to $10 Million (€ 8 Million) in grants to over 125 projects (Aboriginal Affairs and Northern Development Canada).

RELEVANT PROJECTS
AANDC is actively working with Aboriginal communities that are not grid connected to examine sustainable alternatives to diesel fuel generation for the purpose of enhancing economic development opportunities. These solutions may include community-owned renewable energy projects or grid connection (where feasible). During interviews, AANDC highlighted efforts made by the Strategic Partnerships Initiative to improve energy infrastructure for remote communities in Ontario and BC (provinces with the highest numbers of off-grid Aboriginal communities) for the purpose of creating favourable conditions for economic development. AANDC is working with 25 Aboriginal communities in Northern Ontario to examine long term sustainable solutions, such as a regional transmission line and renewable energy projects. The Strategic Partnership Initiative is also working with off-grid Aboriginal communities in British Columbia to assist them in transferring the operations and management of their off-grid generators to the regional utility, BC Hydro. This will allow the communities to take advantage of the subsidies offered by BC Hydro as well as to upgrade and properly maintain their diesel generators, maximizing efficiency and lowering the overall cost of energy production. Communities will also have enhanced opportunities for the development of community-owned renewable energy projects through supports from BC Hydro’s ‘Remote Communities Electrification’ program.

ADDITIONAL SOURCES
(Aboriginal Affairs and Northern Development Canada, 2010, 2011; Leng et al., 2005; Natural Resources Canada, 2011; Sigma Engineering, 1985)
DENMARK

<table>
<thead>
<tr>
<th>CATEGORY 1</th>
<th>REMOTE AREAS WITH LONG WINTERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATEGORY 2</td>
<td>REMOTE AREAS WITH TEMPERATE CLIMATES</td>
</tr>
<tr>
<td>CATEGORY 5</td>
<td>REMOTE RESEARCH STATIONS</td>
</tr>
</tbody>
</table>

OVERVIEW OF REMOTE AREAS

Denmark does not have any communities in its national borders that are disconnected from the central electricity grid. It does, however, consider its two constituent countries Greenland and the Faroe Islands to be remote, which both rely on fossil fuels for a majority of their energy supply. Additionally, Greenland is home to a number of remote research stations including the North Greenland Eemian Ice Drilling project (NEEM).

Because both Greenland and the Faroe islands are autonomous jurisdictions, they do not receive energy subsidies or fall under the energy policies of the Danish government. Denmark does, however, play a role in policy development as an active member of The Nordic Working Group for Sparsely Populated Areas, which also includes Greenland and the Faroe Islands as members. The working group focuses on renewable energy strategies for Nordic regions that are either on the periphery or completely disconnected from central transmission grids.

CURRENT ENERGY POLICY

GREENLAND

Each community in Greenland is responsible for providing its own electricity and heat, as there is no central energy grid to connect to. Most of these communities are heavily reliant on diesel fuel for electricity and heat, and many communities experience high energy prices as a result. Five towns, including the capital Nuuk, have independently built hydropower facilities that provide electricity as well as some heat, and therefore benefit from much lower electricity prices than regions serviced largely or solely by diesel generators.

The national government has come up with a unique way to manage energy costs for the country’s 57,000 inhabitants. It sets heating prices at a flat rate for every customer, so the utility makes a profit in the towns that use hydropower for heat and use that surplus to subsidize the towns that are reliant on diesel fuel. The government has set up a similar scheme for electricity – instead of mandating a flat rate, they have created an artificial ceiling to ensure that customers who rely on imported fuels pay reasonable energy costs, and created an artificial floor so that the hydropower facilities charge more than they need to and cover the cost of the high price of diesel.
**FAROE ISLANDS**

The Faroe Islands have a long history with renewable energy, with the earliest hydropower facility being built in 1921. There are currently six hydropower plants on the island that produced 96 GWh in 2009, 35% of the total island electricity demand of 296 GWh. SEV, the single utility that serves all residents, is currently expanding one of its hydropower facilities located on the main island Eysturoy. Expected to be completed in 2013, the new 8 MW turbine will increase the output by 16.2 GWh annually. SEV also has four 1 MW wind turbines that cover 4% of the islands energy needs.

While electricity is partially covered by renewable energy, the 18,000 homes and buildings island use 60,000 tons of oil imported annually for heating. Additionally, the 61% of the electricity produce in the Faroe Islands that is produced by diesel generators, with a peak load of around 70 MW.

**RELEVANT PROJECTS**

**GREENLAND**

There is significant interest to build more hydropower facilities as well as to explore wind and solar, although given the poor wind resource and high latitude neither technology is cost effective. There is one hydropower facility under construction in the Arctic Circle.

**FAROE ISLANDS**

With the goal of lessening the islands’ dependence on fossil fuels, SEV entered into a joint venture with the Danish utility DONG Energy in 2009 to finance renewable energy development on the Faroe Islands. The Faroe Islands present a unique opportunity for DONG Energy to test renewable energy integration technologies and strategies on an isolated micro-grid. DONG energy has committed to upgrade the existing infrastructure as well as providing funding and resources for new renewable energy development, grid management software, and storage technologies including electric cars. Lessons learned from these projects can be applied to at a larger scale to the European electricity grid.

**ADDITIONAL SOURCES**

(Mikladal, 2005; Sethman, 2011; SEV, 2009; University of Copenhagen, 2011)
OVERVIEW OF REMOTE AREAS

In the context of electricity networks, France defines remote areas as those that are not connected to the continental transmission grid. It has a number of state agencies and other organizations working specifically on and with its remote areas on energy issues. It considers its remote areas to be almost exclusively its island territories and overseas departments.

France has several remote areas, mostly within its many overseas territories and islands. Most of its remote areas are either tropical or sub-tropical islands in the Atlantic, Indian and Pacific Oceans, with the exception of St. Pierre et Miquelon, which is in the north Atlantic. This includes official departments such as Reunion Island, St. Pierre et Miquelon as well as a host of Caribbean islands. It also includes ‘collectivities’ such as New Caledonia and Polynesia, which are now mostly autonomously administered and governed. A map of French overseas departments can be found here: [http://en.wikipedia.org/wiki/File:Outre-mer_en.png](http://en.wikipedia.org/wiki/File:Outre-mer_en.png)

Additionally, France has two remote research stations located in Antarctica: Concordia Station, which is shared with Italy, and Dumont d'Urville Station.

CURRENT ENERGY POLICY

France does have a number of policies in place to address energy challenges facing remote communities. To offset high fuel costs, the price of electricity is subsidized across Corsica, Guadeloupe, Martinique, French Guyana, Reunion Island, Mayotte, St. Pierre et Miquelon, St. Barthélémy, St. Martin (but not in French overseas territories such as New Caledonia and Polynesia), so that island residents pay the same electricity prices as customers on France’s continental grid.

Another policy designed to address energy concerns in remote communities is its national “tarifs d’achat”, or feed-in tariffs in French overseas departments (but not in French overseas territories such as New Caledonia or Polynesia), which include higher tariffs targeted at projects in France’s remote regions and islands. So far, the outcomes of the feed-in tariffs have been good – solar PV in particular is increasingly popular on many of its territories, most notably in La Reunion.
RELEVANT PROJECTS

One interesting project being undertaken by France is the Millener project in French overseas territories (Reunion Island, Guadeloupe and Corsica) where the utility Electricité de France is equipping 500 homes with grid-connected solar PV associated with battery banks, with the help of European, regional and government subsidies. The aim of the Millener project is to improve the integration of renewable energy sources and to contribute to power grid balance and stability. France is also working on a few different projects involving large-scale (multi-megawatt) storage to help improve power reliability: sodium sulfur in Reunion Island, sea water pumped-storage power plant in Guadeloupe. The feed-in tariffs have also enabled independent power producers in islands ranging from Guadeloupe to Reunion Island to sell their power to the grid. This has led to thousands of small-scale renewable energy projects throughout France’s overseas departments. The government is organizing call for tenders for wind and photovoltaic generation coupled with electricity storage.
OVERVIEW OF REMOTE AREAS
Germany is densely populated and has no known communities within the country that are heavily reliant on diesel power or are completely disconnected from the central power grid. One of Germany’s last remaining remote islands, Helgoland, was recently connected to the mainland grid as part of an effort to extend transmission lines to an offshore wind energy project.

Outside of the country, Germany does have three research stations in Antarctica: Neumayer Station, Neumayer-Station III, and Kohnen-Station.

CURRENT ENERGY POLICY
Without any major isolated areas, no relevant energy policies could be identified.

RELEVANT PROJECTS
Representatives from the Fraunhofer Institute were interviewed to discuss the Institute’s projects to bring solar power to specific buildings (e.g. hotels and inns in remote areas such as the Black Forest). Since these efforts supported stand-alone installations and not remote communities, however, they were judged to be beyond the scope of the project.

ADDITIONAL SOURCES
(TRACTO-TECHNIK, 2009)
OVERVIEW OF REMOTE AREAS
A representative of the Sustainable Energy Authority of Ireland (SEAI) was interviewed for this report. SEAI reported that they were unaware of any national definition of remote areas. Furthermore, while there are areas that are considered rural, SEAI is not familiar with populated areas in Ireland that did not have a grid connection.

CURRENT ENERGY POLICY
Without any major isolated areas, no relevant energy policies could be identified.

RELEVANT PROJECTS
SEAI is currently piloting smart grid technologies on the Aran Islands.

The Aran Islands are connected to the mainland via an underwater cable. SEAI saw this location as an opportunity to research the infrastructure impact of supplying 80% of a given area's electricity demand with wind, wave, and tidal power.

In order to achieve this goal, the SEAI is testing an intelligent storage system using electric cars. Through this system, electric cars connected to the energy grid would provide a solution to the intermittency problem with wind and wave technology by serving as storage when needed.

To successfully implement its intelligent EV storage system, SEAI is seeking to better understand the driving habits of the residents as well as the performance of new technologies that can balance supply and demand on the grid. The pilot program includes the installation of a 675 kW wind farm that runs a desalination plant and powers 8 electric cars.

ADDITIONAL SOURCES
(McDonald, 2011; Siggins, 2011; Sustainable Energy Association of Ireland, 2011)
OVERVIEW OF REMOTE AREAS
Japan is made up of 6,852 islands including the main islands of Honshu, Hokkaido, Kyushu, Shikoku, and Okinawa. The remaining 6,847 islands, covering a total area of about 5,250 square kilometers of area, are treated as remote areas. Of these, approximately 430 are inhabited. It is estimated from the 2005 census that there are 435,000 inhabitants in these remote areas, an 8% drop from 2000 when the population was 470,000. Of these islands, 70 have populations of less than 500 inhabitants.

Additionally, Japan has four remote research stations in Antarctica: Asuka Station, Mizuho Station, Showa Station, and Dome Fuji Station.

CURRENT ENERGY POLICY
Japan’s policy focus on its remote islands builds on the Rural Island Development Act of 1953, which was originally developed to improve the quality of life for island residents. The law enables the funding and implementation of a development plan for remote islands that is renewed every 10 years. The most recent iteration was implemented in 2003 and carries through March 2013.

In the Ministry of Land, Infrastructure, Transport and Tourism (MLITT)’s 2003 Remote Island Development Policy memorandum, Japan further outlines its commitment to promoting economic development on remote islands. The document provides support for taking advantage of abundant wind, wave, and tidal power, reducing transportation costs, and integrating infrastructure for zero-emissions cars. To date, these policy commitments have not been translated into concrete legislation or programs to support renewable energy development specifically in remote areas.

Japan has taken action to reduce existing energy costs for residents of remote islands. The regional utilities are required to provide electricity to every customer at the same price. The high cost of supplying power to remote regions is therefore shared equally within their service territories.

RELEVANT PROJECTS
In 1999, the Okinawa Electric Power Company developed the world’s first seawater pumped-storage facility. The system consists of a reservoir with a storage capacity of 564,000 cubic meters 150 meters above sea level. The power station is located 136 meters below the reservoir, and can produce up to 30 MW of electricity, which is around 2% of the maximum power demand for Okinawa Island.

ADDITIONAL SOURCES
(HIRONAO ET AL., 2010; JOHNSON, 2011)
OVERVIEW OF REMOTE AREAS

Similar to Denmark and France, the Netherlands has a number of overseas territories that are isolated from centralized energy infrastructure. Formerly known as the Netherlands Antilles, the Kingdom of the Netherlands includes three constituent countries of Aruba, Curacao, and St. Maarten, and the three “special municipalities” of Bonaire, Saint Eustatius, and Saba (BES). As of 2009, these six islands combined had a total population of 227,049. While the extent of governance of the constituent countries does not extend to energy policy, the Netherlands does partially manage energy policy for its special municipalities.

Figure 2: Map of the Netherlands Overseas Constituent Countries and Special Municipalities

---

67 The former Netherlands Antilles (6 islands) no longer exist: Since October 10, 2010 three islands (Curacao, Aruba and St. Maarten) are OCT’s (overseas countries and territories) but the three BES islands (Bonaire, St. Eustatius and Saba) have a status somewhere between OCT and OMR (outermost regions). In the Netherlands constitution the BES are special local communities/towns. Their (EU) status will be evaluated within five years after 2010 and a final status well probably then be decided. The legal/constitutional status of the BES is relevant e.g. for EU legislation (e.g. the EU renewable energy directive does not apply now) and trade relations. However, the BES - being part of the Kingdom of the Netherlands- may apply for EU programmes, e.g. regional programmes and the EU framework programme for R&D.
CURRENT ENERGY POLICY
The Ministry of Economic Affairs, Agriculture and Innovation helps the BES islands with their energy policy although formally they are independent to decide on their own; the Dutch government does not interfere in energy pricing. Inhabitants of Bonaire, Saint Eustatius, and Saba pay on average US$0.30-0.35 per kWh of electricity to the local government-owned utility, which sets and manages the prices. The price is not heavily subsidized, and reasonably reflects the actual production cost.

The Dutch government is looking together with the local government to use the strong wind resource on the islands to shift away from a heavy dependence on diesel power. While the feed-in tariff used to incentivize renewable energy in the Netherlands is not applicable here, the tax deductions are available to developers.

RELEVANT PROJECTS
Ecofys recently completed a hybrid wind-diesel facility on the island of Bonaire that provides electricity for its 15,800 inhabitants: 11 MW of wind power provides 50% of electricity demand, while a 15 MW diesel facility coupled with a 3 MW battery provides the necessary base power and backup to maintain power quality. The project, which went online in August 2009, took four years to complete.
### Norway

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>Remote Areas with Long Winters</td>
</tr>
<tr>
<td>Category 2</td>
<td>Remote Areas with Temperate Climates</td>
</tr>
<tr>
<td>Category 5</td>
<td>Remote Research Stations</td>
</tr>
</tbody>
</table>

### Overview of Remote Areas

Norway has set nationally recognized guidelines on what constitutes a remote region. Statistics Norway (SSB) differentiates a densely populated area from a sparsely populated area using two key criteria:

1. A cluster of houses with a total population of at least 200 people (approximately 60-70 houses).
2. The distance between the houses does not exceed 50 meters\(^{68}\). Houses up to 400 meters from the center of the community are included in the count.

Sparsely populated areas are all populated areas that do not fit into the definition of being densely populated, as defined above.

Whether or not a region is considered remote is directly built into the tax code, and has certain implications on what residents and businesses pay to the national government. The Ministry of Finance has defined 5 separate zones based on their level of remoteness, as seen in Figure 3.

---

\(^{68}\) This distance is not absolute. Exceptions to the definition can for instance be if there is a park, industrial area, sports arena, etc. that causes the distance between houses to be greater than 50 meters.
Zone 5 in the northernmost region includes the 19 municipalities in Finnmark County plus the 7 northernmost municipalities in Troms County. Statistics Norway estimates that there are 341,003 inhabitants of these remote areas.

Residents of Zone 1 pay the highest rate of employers’ tax, while residents of Finnmark County, Troms County, and Nordland County in Zone 5 and the northern portion of Zone 4 are exempt from employers’ tax and value added tax (VAT) on any energy purchase. Residents from Zone 5 also pay a reduced energy tax of 0.0045 NOK/kWh (€ 0.0006/kWh) compared to the residents of Zone 1 who pay 0.1121 NOK/kWh (€ 0.0143/kWh) + an additional 25% VAT.

REMOTE RESEARCH STATIONS
In addition to the remote areas located within Norway, the country has two remote research stations located in Antarctica: Tor Station and Troll Station.

CURRENT ENERGY POLICY
In Norway, every household is entitled to be interconnected to the national energy grid, regardless of their location. The law further mandates that if the household is a permanent residence that the utility must share in the cost of grid connection. This mandate does not extend to temporary residences, which are also entitled to a grid connection but must cover the full cost. It is for this reason that over 100,000 out of the 400,000 “weekend cottages” around Norway are not grid connected and instead rely on solar PV.

As a result of this law, it is expensive for utilities to build and maintain these remote grid connections. To offset this cost and to prevent rate hikes for remote households, the Norwegian government will
provide the affected utilities grants annually. In 2011, these grants amounted to NOK 60 Million (€ 7.64 Million) and were split between 24 distribution companies.

Table 15: Grants to Utility Companies

<table>
<thead>
<tr>
<th>Solkap</th>
<th>År</th>
<th>(kroner)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austevoll Kraftlag BA</td>
<td>2011</td>
<td>2,925</td>
</tr>
<tr>
<td>Ballangen Energi AS</td>
<td>2011</td>
<td>2,647</td>
</tr>
<tr>
<td>Bindal Kraftlag SA</td>
<td>2011</td>
<td>1,444</td>
</tr>
<tr>
<td>Orangedal Elverk KF</td>
<td>2011</td>
<td>2,219</td>
</tr>
<tr>
<td>Eirenes Kraftsorings AS</td>
<td>2011</td>
<td>1,992</td>
</tr>
<tr>
<td>Eiger Kraftlag PL</td>
<td>2011</td>
<td>2,298</td>
</tr>
<tr>
<td>Folsberg Kraftlag</td>
<td>2011</td>
<td>645</td>
</tr>
<tr>
<td>Flekke Kraftlag</td>
<td>2011</td>
<td>1,227</td>
</tr>
<tr>
<td>Forsand Elverk KF</td>
<td>2011</td>
<td>476</td>
</tr>
<tr>
<td>Gusa Kraftlag</td>
<td>2011</td>
<td>4,632</td>
</tr>
<tr>
<td>24</td>
<td>3,120</td>
<td></td>
</tr>
<tr>
<td>Hærling Kraftlag</td>
<td>2011</td>
<td>3,120</td>
</tr>
<tr>
<td>Hortdal Elverk</td>
<td>2011</td>
<td>1,212</td>
</tr>
<tr>
<td>Kvikne-Rennebu Kraftlag A/L</td>
<td>2011</td>
<td>756</td>
</tr>
<tr>
<td>Modalen Kraftlag BA</td>
<td>2011</td>
<td>175</td>
</tr>
<tr>
<td>Nord-Salen Kraftlag AL</td>
<td>2011</td>
<td>3,444</td>
</tr>
<tr>
<td>Nore Energi AS</td>
<td>2011</td>
<td>1,105</td>
</tr>
<tr>
<td>Paurand Kraftsoringslag</td>
<td>2011</td>
<td>2,497</td>
</tr>
<tr>
<td>Pepuvåg Kraftlag AL</td>
<td>2011</td>
<td>4,107</td>
</tr>
<tr>
<td>Påløy-Lutøy Kraftverk AS</td>
<td>2011</td>
<td>8,431</td>
</tr>
<tr>
<td>San-Aurdal Energi BA</td>
<td>2011</td>
<td>687</td>
</tr>
<tr>
<td>Tydal Komm Enerverk KA</td>
<td>2011</td>
<td>986</td>
</tr>
<tr>
<td>Tynnes Kraftlag SA</td>
<td>2011</td>
<td>9,411</td>
</tr>
<tr>
<td>Utvåg Kraftsorings AS</td>
<td>2011</td>
<td>2,159</td>
</tr>
<tr>
<td>Vang Energiverk</td>
<td>2011</td>
<td>1,391</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>60,000</td>
</tr>
</tbody>
</table>

RELEVANT PROJECTS
While most of the focus of the Norwegian government has been to connect the entire country to the existing grid infrastructure, there have been a few initiatives to use local renewable energy as a means to provide power to remote communities. In 2004, two 600 kW turbines and a fuel cell were built on the Island of Utsira, located 200 miles from Oslo. The wind turbines produce hydrogen which feeds the fuel cell to produce energy when the wind is not blowing, thereby providing a base load source of electricity that can be dispatched on demand.

ADDITIONAL SOURCES
(msnbc.com news services, 2005; Statistics Norway, 2011; Suul et al., 2008)
Representatives from the UK Department of Energy and Climate Change (DECC) were unaware of any national definition of remote areas or specific energy policies that focus on remote areas. However, they identified region-specific initiatives to define remote areas and to address the energy concerns in Scotland. The UK also has jurisdiction over fourteen British Overseas Territories, ranging from the Falkland Islands in the South Atlantic, to the Pitcairn Islands in the Pacific, Anguilla and Montserrat in the Caribbean, and British Antarctic Territory in Antarctica. A map of the British Overseas Territories can be found here: http://en.wikipedia.org/wiki/File:British_Overseas_Territories.svg. This section focuses primarily on Scotland, but includes an illustrative description of projects underway in the Falkland Islands at the end of this section.

**SCOTLAND**

The Rural and Environmental Research and Analysis Directorate of the Scottish Government has produced a study of urban and rural areas in Scotland. The study, entitled *Scottish Government Urban/Rural Classification*, outlines their 8-fold classification structure to define a settlement based on the population of that settlement and the distance to a larger settlement.

The Scottish classification methodology is focused primarily on geographic remoteness, without consideration for infrastructure remoteness or economic remoteness. Other than the Shetland Islands, which have their own energy micro-grid, it is unclear if and where other areas exist that are disconnected from the central energy grid.

Table 8 summarizes the parameters of the Scottish classification.
Table 16: Scottish Government 8-Fold Urban/Rural Classification (The Scottish Government, 2010).

<table>
<thead>
<tr>
<th>Class</th>
<th>Class Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Large Urban Areas</td>
<td>Settlements of over 125,000 people.</td>
</tr>
<tr>
<td>2</td>
<td>Other Urban Areas</td>
<td>Settlements of 10,000 to 125,000 people.</td>
</tr>
<tr>
<td>3</td>
<td>Accessible Small Towns</td>
<td>Settlements of between 3,000 and 10,000 people, and within a 30 minute drive time of a Settlement of 10,000 or more.</td>
</tr>
<tr>
<td>4</td>
<td>Remote Small Towns</td>
<td>Settlements of between 3,000 and 10,000 people, and with a drive time between 30 and 60 minutes to a Settlement of 10,000 or more.</td>
</tr>
<tr>
<td>5</td>
<td>Very Remote Small Towns</td>
<td>Settlements of between 3,000 and 10,000 people, and with a drive time of over 60 minutes to a Settlement of 10,000 or more.</td>
</tr>
<tr>
<td>6</td>
<td>Accessible Rural Areas</td>
<td>Areas with a population of less than 3,000 people, and within a drive time of 30 minutes to a Settlement of 10,000 or more.</td>
</tr>
<tr>
<td>7</td>
<td>Remote Rural Areas</td>
<td>Areas with a population of less than 3,000 people, and with a drive time of between 30 and 60 minutes to a Settlement of 10,000 or more.</td>
</tr>
<tr>
<td>8</td>
<td>Very Remote Rural Areas</td>
<td>Areas with a population of less than 3,000 people, and with a drive time of over 60 minutes to a Settlement of 10,000 or more.</td>
</tr>
</tbody>
</table>

The Scottish Government GI Science and Analysis Team has created a map layer based on the Urban/Rural classification. Figure 4 shows most of the areas classified as Very Rural Remote to be in the northern regions as well as the surrounding islands.
REMOTE RESEARCH STATIONS

The UK has three remote research stations located in Antarctica: Halley Research Station, Rothera Research Station, and Signy Research Station.

CURRENT ENERGY POLICY

SCOTLAND

Scotland has set ambitious goals for its renewable energy policy. With a quarter of its electricity already being met with renewable energy, the Scottish government has set the goal to reach 100% of its electricity demand and 11% of its heating demand from renewable energy by 2020. Outlined in the 2020 Routemap for Renewable Energy in Scotland, the government has set the goal of 500 MW of this energy to come from community-focused projects. To enable this, the government has already enacted a feed-in tariff as well as renewable heat incentives.
Scotland has set up programs to address energy concerns for geographically remote areas. According to a report compiled by the Rural Development Council entitled *Scotland Rural Future*, in 2009 the Scottish government developed home insulation rebates for up to £145 (€168) that are available to 390,000 properties in 29 rural authorities. The Energy Saving Trust of Scotland discloses that this initiative has saved homeowners £1,407,726 (€1,638,452.29) since its inception.

The Scottish government is also currently planning a High Voltage Direct Current (HVDC) subsea cable that will connect the Western and Northern Isles to the national grid. This cable, with a capacity of 450 MW, is expected to take advantage of significant wind, tidal, and wave resource available in the remote areas of the Western Isles. While the primary intent is to bring power back to the mainland, the Scottish government recognizes the additional benefit that this cable will bring to these regions by lowering the cost of energy and driving economic growth.

The energy programs that are in place cover all geographically rural areas, regardless of whether or not they are grid-connected. It is unclear how Scotland is planning to address areas like the Shetland Islands that do not have a central grid connection to reach their aggressive renewable energy goals. More research should be done to understand:

- If there are any places other than the Shetland Islands disconnected from the central energy grid, and where they are,
- How the 100% renewable energy targets apply, and
- How they plan to address renewable energy integration in these places.

This example may prove to be one of the most interesting opportunities for future policy development. Scotland is going to have to solve many of the grid integration concerns that remote areas face in the next decade, and address their strategy for areas that are disconnected from central infrastructure.

**RELEVANT PROJECTS**

**SCOTLAND**

Scotland is also taking advantage of these available resources for smaller community-focused projects. The Isle of Eigg, with a population of 67 people off the west coast, recently installed a renewable energy system that covers 100% of the community’s energy needs. This system includes 30 kW of solar PV, three hydro generation systems that total 119 kW, and four 6 kW wind generators. Two 80 kW diesel generators are available as standby power if necessary.

Given the intermittency of the renewable sources used, the Isle of Eigg has taken steps to manage the available supply to match demand. A bank of batteries is connected through a series of linked inverters to the distribution grid, which allow immediate control over how much electricity is available at any given moment. The utility has also capped electricity supply at 5 kW for its residential and small business customers and 10 kW for its commercial customers. Customers are required to manage their own demand, and are provided with smart meters that allow them to monitor their current usage. A £25 fine is incurred if this cap is exceeded.
THE FALKLAND ISLANDS
The Falkland Islands, with a population of 2,995, is a British Overseas Territory that has made a significant push in the past few years to develop renewable energy. In February 2010, the completion of the Sand Bay Wind Farm, located six miles from the Island’s capital Stanley, will bring total renewable energy production for the island up to 2 MW. The wind farm is comprised of six 330 kW wind turbines and a 2 MWh battery for storage and grid management, and will cover 40% of the island’s energy needs.

This wind farm has positively impacted an island that previously relied heavily on diesel generation. The benefits have been particularly great for farms, which previously could only afford to purchase electricity for a few hours each day. Today, with funding assistance from the Falkland Islands Development Corporation, 85% of farms now have 24-hour power from renewable sources.

ADDITIONAL SOURCES
APPENDIX C: POWER QUALITY OVERVIEW

Remote and islanded communities often suffer from an inferior quality of electric service. There are five broad characteristics of power quality: reliability, voltage, frequency, power factor, and waveform distortions. The two characteristics of power quality that are of most interest to remote communities are reliability and voltage. Within these power quality characteristics, however, the primary aspects of concern are: interruptions and voltage sags. Definitively, interruptions cause the most severe impact on the customer, involving a complete loss of electrical power often for an unknown period of time.

Globally, there are numerous metrics used to assess customer interruptions. These metrics fall into three categories that describe interrupting events by:

a) the quantity of events over a fixed period,

b) the duration of events, and

c) event severity.

The description of severity is more difficult to determine and typically is expressed in terms of the electrical capacity of the affected area or the monetary cost of interrupting events (e.g. shutdown that affects industry, a hospital, or other critical infrastructure). The following chart annotates some of the most common transmission and distribution (T&D) system interruption metrics used in North American and Europe.

For remote and islanded communities, measures of interruption severity are highly variable. However, the frequency and duration of interruptions are meaningful proxies for describing the impact of electricity loss to a remote or islanded community. Therefore, three common utility metrics for interruptions are suggested for classifying interruptions: System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), and Average Service Availability Index (ASAI). SAIFI and SAIDI are closely related, describing how often and for how long electrical blackouts last, respectively. They are typically calculated on an annual basis, but may be calculated over shorter periods to analyze the reliability of electrical service. A slightly more general measure of electrical reliability is ASAI which gives a measure of the annual outage time experienced by customers.

<table>
<thead>
<tr>
<th>Interruption Index</th>
<th>Category</th>
<th>Area of Usage</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>System average interruption frequency index (SAIFI)</td>
<td>Quantity</td>
<td>North America, EU</td>
<td>IEEE Std 1366 CIGRE JWG C4.07</td>
</tr>
<tr>
<td>System average interruption frequency index for momentary interruptions (SAIFI-MI)</td>
<td>Quantity</td>
<td>Canada</td>
<td>CEA</td>
</tr>
<tr>
<td>System average interruption frequency index for sustained interruptions (SAIFI-SI)</td>
<td>Quantity</td>
<td>Canada</td>
<td>CEA</td>
</tr>
<tr>
<td>Loss of Supply Incidents</td>
<td>Quantity</td>
<td>UK</td>
<td>National Grid</td>
</tr>
<tr>
<td><strong>System average interruption duration index (SAIDI)</strong></td>
<td><strong>Duration</strong></td>
<td><strong>North America, EU</strong></td>
<td><strong>IEEE Std 1366 CIGRE JWG C4.07</strong></td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>--------------</td>
<td>-----------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td><strong>System average restoration index (SAIRI)</strong></td>
<td><strong>Duration</strong></td>
<td><strong>EU</strong></td>
<td><strong>CIGRE JWG C4.07</strong></td>
</tr>
<tr>
<td><strong>Continuity index (CI)</strong></td>
<td><strong>Duration</strong></td>
<td><strong>Canada</strong></td>
<td><strong>CEA</strong></td>
</tr>
<tr>
<td><strong>Average incident duration</strong></td>
<td><strong>Duration</strong></td>
<td><strong>UK</strong></td>
<td><strong>National Grid</strong></td>
</tr>
<tr>
<td><strong>Average interruption time (AIT)</strong></td>
<td><strong>Duration</strong></td>
<td><strong>UNIPEDE</strong></td>
<td><strong>SystQual Ref. 04000, Ren 9706</strong></td>
</tr>
<tr>
<td><strong>Energy not supplied (ENS)</strong></td>
<td><strong>Severity</strong></td>
<td><strong>UK</strong></td>
<td><strong>National Grid</strong></td>
</tr>
<tr>
<td><strong>Interruption severity index</strong></td>
<td><strong>Severity</strong></td>
<td><strong>UNIPEDE</strong></td>
<td><strong>SystQual Ref. 04000, Ren 9706</strong></td>
</tr>
<tr>
<td><strong>System minutes</strong></td>
<td><strong>Severity</strong></td>
<td><strong>UNIPEDE</strong></td>
<td><strong>CIGRE JWG C4.07</strong></td>
</tr>
<tr>
<td><strong>Interruption cost index (IC)</strong></td>
<td><strong>Severity</strong></td>
<td><strong>Norway</strong></td>
<td><strong>NVE</strong></td>
</tr>
</tbody>
</table>

\[
SAIFI = \frac{\text{Total Number of Customers Interrupted}}{\text{Total Number of Customers Served}} = \sum \frac{N_i}{N_t} \\
SAIDI = \frac{\text{Total Duration of Customer Interruptions}}{\text{Total Number of Customers Served}} = \sum \frac{r_i N_i}{N_t} \\
ASAI = \frac{\text{Customer Hours of Electricity Availability}}{\text{Customer Hours of Electricity Demand}} = \frac{N_t \eta - \sum r_i N_i}{N_t \eta}
\]

Where, \( N_i \) is the number of customers that experience an interruption, \( N_t \) is the number of customers in an area, \( \eta \) is the analysis period (typically 8,760 hrs/yr), \( r_i \) is the restoration time. Restoration time is defined as the period elapsed from the interrupting event to complete recovery of electrical service to the customer.

Apart from electricity interruptions, voltage quality issues are the most common power quality issue and can cause improper equipment operation or damage. In many cases, the customer is unaware of voltage quality disruption, but unstable voltages can have significant impacts on the operation of electrical devices, the service lives of equipment, and the efficiency of the overall system. By far the most prevalent voltage quality issue is the brown-out which results from a sag or dip in voltage. Other
significant issues, but of lesser concern, are: power surges causing an undesirable increase in voltage and fast voltage flickers that are transient waveform distortions.

Voltage sag duration, severity, and characteristics remain a topic of on-going investigation by the power engineering community. Due to their complexity, voltage sags are difficult to classify in meaningful ways. Despite the challenges, standards organizations in both in North America, the IEEE Project Group P1159, and in Europe, the joint CIGRE/CIRED/UE Working Group C4.110, are attempting to develop indices, similar to those for interruptions, to describe voltage sags. However, guidelines have not been published, nor are yet in use. More generally, in order to discriminate the difference between a voltage sag (brownout) and an interrupting event (blackout, interruption, or outage), the IEEE Standard 1159 defines a voltage sag as lasting between 1/120 of a second up to a minute. Low voltage events that last longer than a minute can be considered an interruption or outage. The typical causes of voltage sags are inadequate capacity from the generation source, while short circuits or an unplanned loss of a generator or transmission lines are the most common causes of unplanned outages.

Every utility scale alternating current electric system operates at a fundamental frequency, either 50 or 60 Hz. In reality, the actual frequency varies slightly around this standard. On large interconnected systems these variations are limited by regulations within a very tight range. Typically, each nation or major interconnection establishes frequency and voltage service requirements with grid codes. The grid codes specify the boundaries for frequency variation under normal (called continuous) operation, as well as expanded boundaries for short- and medium-term emergencies. The rigidity of grid codes varies within IEA-RETD countries with Germany and Norway mandating the most restrictive continuous boundaries (49.0 - 50.5 Hz), to the UK with wider continuous boundaries (47.5 - 52.0 Hz). On isolated systems, the frequency variations are often larger because they lack the contribution of very large centralized power plants which exert significant stability on the interconnected system. However, in isolated systems, frequency variation is a lesser concern than the reliability and voltage stability factors. This, in part, is due to the characteristics of electricity usage in remote areas where load is characterized by robust appliances and fewer sensitive devices.

Power factor refers to the phase relationship between the voltage and current waveforms. A phase difference arises due to the inductive and capacitive natures of components attached to the power system. These reactive components, including transformers, motors, power supplies, lighting systems, etc., have inherent magnetic and electrostatic characteristics that demand very short-term power for storage requirements. These characteristics do not yield any benefit towards the delivery of electrical power, but they must be satisfied for the system to work properly. Ideally, if the system did not have these components, voltage and current would be exactly in phase, yielding a power factor of 100%. Clearly this is not possible, and as a result the power factors of electrical networks are less than ideal. Power systems, therefore, must be operated considering the excess currents that flow over transmission and distribution lines to reactive components. Ultimately, poor power factors cause the electrical network to work with larger margins to operational limits, transfer electrical energy less efficiently, and potentially can cause undesirable equipment heating, leading to failures.
There are a variety of ways that voltage and current waveforms can be distorted within power systems. The most common distortions are harmonics introduced by certain kinds of “noisy” loads that cause many small transient events on the system. As power electronic switches operate within components such as lighting, power supplies, and consumer electronics, very rapid pulses are introduced onto the line. Although the summation of many noisy components can create sizeable distortions in voltage and current, harmonic effects are typically very local phenomenon and only the most extreme distortions are problematic. In general, harmonics are of low concern for remote and isolated areas.
BIBLIOGRAPHY


dentification/IBSEV_EN


---

**IEA-RETD REMOTE**


McDonald, B. (2011, January 15). Project’s a breeze for islanders with wind-powered electric cars. *Independent.ie*.


National Biodiesel Board. (2007). *Biodiesel cold flow basics: Information for petroleum distributors, blenders, and end-users on issues affecting biodiesel in the winter months*. Washington, DC.


Siggins, L. (2011, January 1). Eight families go electric in Aran Islands pilot project. *Irish Times*.


TRACTO-TECHNIK. (2009). *E.ON Hanse connects the island of Helgoland to the power network*. Lennestadt, Germany.


