ICE REPORT 2.1.1

SMART PERIPHERAL TERRITORIES TRANSITIONS:
LITERATURE REVIEW AND CURRENT STATUS

19/06/18

George Jr. Matthew, Oscar Fitch-Roy, Peter Connor & Bridget Woodman, University of Exeter

About ICE

Supported by Interreg VA France (Channel) England, the Intelligent Community Energy (ICE) project, aims to design and implement innovative smart energy solutions for isolated territories in the Channel area. Islands and isolated communities face unique energy challenges. Many islands have no connection to wider electricity distribution systems and are dependent on imported energy supplies, typically fossil fuel driven. The energy systems that isolated communities depend on tend to be less reliable, more expensive and have more associated greenhouse gas (GHG) emissions than mainland grid systems. In response to these problems, the ICE project considers the entire energy cycle, from production to consumption, and integrates new and established technologies in order to deliver innovative energy system solutions. These solutions will be implemented and tested at our unique pilot demonstration sites (Ushant island and the University of East Anglia's campus), to demonstrate their feasibility and to develop a general model for isolated smart energy systems elsewhere. The ICE consortium brings together researcher and business support organisations in France and the UK, and engagement with SMEs will support project rollout and promote European cooperation.

Executive summary

There is a wide range of literature relevant to smart energy island transitions. The insights afforded by a general literature addressing electricity system planning, has been incorporated into a burgeoning literature produced by practitioners and analysists tackling smart energy islands. At the same time, numerous islands and other peripheral communities have embarked on smart or sustainable energy transitions. By combing the numerical modelling approaches often used to guide planning decisions with what can be learnt from 'real-world' experiences provides a view on the opportunities and challenges facing island energy systems. This report also suggests a number of 'best practices' or pieces of general advice that can cut across the wide variations in physical, economic and cultural contexts, unique to each island community. We propose these to be:

- **Adopt new technologies:** The particular challenges of island energy systems mean that novel and new technologies will be especially valuable
- **Engage local communities:** Creating a new form of energy system cannot be driven from the top-down. It is vital that not only is community engagement seen as a tool for removing resistance to change, but that the nature, timing and extent of change is the result of real discussions among system participants
- **Involve local enterprise:** The long-term economic benefits of the transition may be associated with ongoing provision of goods and services by island companies
- **Invest in skills and capacity:** In many small communities, the capacity and skills required to undertake an energy system transition are very limited. Strategic decisions about the skills to be fostered may build long term economic resilience
- **Consider alternative business models:** It may be the case that community-led or locally-owned energy ventures are better suited to island contexts than traditional utility business models
- **Play to your strengths, but be realistic about supply options**: Many islands have impressive energy resources, but these are often concentrated in one or two resources, limiting the ability to rely solely on these resources
- **Use energy wisely**: By reducing overall demand peaks as well as making energy demand more responsive to resource availability may reduce the cost of generation and distribution as well as actively contributing to system reliability

These best practices are reflected in a series of interrelated actions, assembled as a guide for island communities pursuing a smart energy transition. The so-called 'ICE methodology' to transitions incorporates and elucidates seven key steps and is provided as ICE deliverable number: T2.1.2.

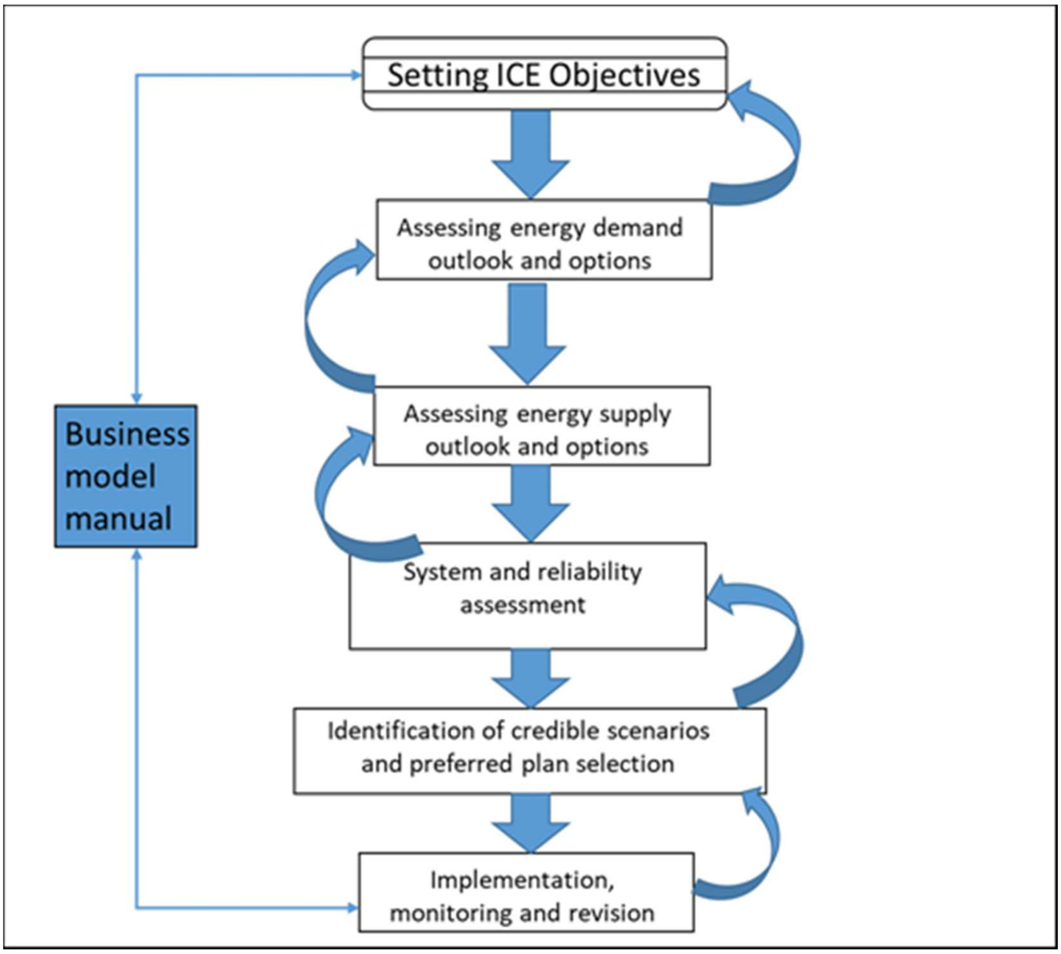
Setting ICE Objectives
Assessing energy demand outlook and options
Assessing energy supply outlook and options
System and reliability assessment
Identification of credible scenarios and preferred plan selection
Implementation, monitoring and revision
Business model manual

Table of Contents

List of figures

List of Tables

1. Introduction

The ICE project aims to provide a guide for isolated communities to develop a plan for transition to a smarter energy system, integrating low carbon electricity generation, and demand reduction. This document presents a general methodology for planning for this smart energy transition to inform isolated communities: the ICE methodology.

This document provides a review of the current status of smart island energy transitions and is complementary with document T2.1.2, which operationalises the findings in the form of an 'ICE methodology'. It begins with a survey of examples of smart energy island transitions and established experience in determining known approaches to electricity system planning in general and smart energy islands in particular. The resulting synthesis is a proposed general methodology that can be applied for establishing plans for smart energy transitions. The approach will be validated for various islands or peripheral communities as part of the ongoing ICE project implementation.

The second part of the document reviews several real-world smart energy programmes in isolated territories. An overview of ways to understand a smart energy transition such as by modelling and doing real-world implementations is presented. Then drawing from a host of European and Worldwide examples the scale of past and present island smart energy transition and related projects is examined. A discussion of the lessons learnt from these implemented projects and strategies are elicited based on several key criteria including technological selection and impacts, policy and sustainable development, financial and economic implications as well as stakeholder engagement. From these discussions some key opportunities and challenges of the smart energy transition in isolated and peripheral areas is highlighted. The third section of the document lays out the specific considerations of the proposed generic methodology for the isolated system smart energy transition. The conceptual overview of the methodology is presented and the rationale behind this choice of framework is supported.

2. Approaches to analysing smart energy island transition programmes

This section outlines the main approaches available for analysing smart energy island programmes. The ICE project's aim to design and implement innovative smart energy solutions within isolated territories of the English Channel area fits well within the global trend for sustainable energy. As social and environmental demands on electricity systems evolve, they are tending away from traditional passive, centralised fossil-based supply focussed systems and towards more dynamic and decentralised low-carbon, incorporating 'smarter' technologies and practices of architecture. This includes isolated or remote systems, which have often acted as test beds for change (Vallvé, 2013; Islands Energy Program, 2016). Future electricity systems must be observable, controllable, automated and fully integrated (Bompard *et al.*, 2012). These systems should intelligently integrate the actions of all users connected to it - generators, consumers, actors that do both ("prosumers") and other existing and potential market and network service providers, in order to deliver sustainable, economic and secure electricity supply. Achieving these aims requires significant social and technological change in both the short and the long-term (US DoE, 2004). The enabling 'smart' technologies required by such a system can be thought of as a mix of data collection, processing and operational facilitation (MIT, 2011).

The conditions in individual remote and peripheral communities are extremely diverse, with different climates, economies, energy resource availability, political and institutional contexts and cultures (IEA, 2012). This context-specificity means that that there is no "one-size fits all" approach to realising sustainable energy transitions in isolated or peripheral settings. Therefore, an appreciation of the specific context is the starting point for a plan to guide or promote transition to a smarter electricity system in any isolated or peripheral community. Nevertheless, there are experiences that recur across these diverse territories, offering examples of common pitfalls and suggesting models that can contribute to the establishment of best practice. The following sections survey the current state of the art in smart energy islands and distils the experience gained into some general, implementable lessons.

Section 2.1 outlines the general considerations for studying smart energy islands; section 2.2 discusses approaches to modelling island systems and section 2.3 previews the study of existing and ongoing programmes.

2.1 Studying smart energy island transitions

Small island systems have been studied extensively in the past decade as "living laboratories" for sustainable energy solutions. For example, multiple EU islands and peripheral territories (such as Pellworm and Samsø (ISRER, 2010; Visit Samsoe, 2017)) began to consider the transition to becoming renewable energy based in the 1990s. As renewables became more commonplace within these systems and accounted for larger volumes of production, it became apparent that integration of multiple generating technologies could be done more effectively with smarter systemic approaches rather than the traditional passive approach. Similar approaches have spread as a method for assisting in widening energy access and improving security of supply in small island developing states. This includes islands in the Pacific and Indian Oceans and in the Caribbean (SmileGov, 2009; IRENA, 2014a, 2014b, 2015, 2017; ETI, 2017). This has led to a rich repository of available data useful for electricity system designers, policy makers and modellers. These prior studies provide a useful perspective on the type and quality of future electricity system that is possible. By acknowledging the unique dynamics and the often-low levels of complexity in small, isolated systems, the results of these studies can be transferred to other island electricity systems that are embarking on a smart energy transition. Current and ongoing approaches to smart energy transition are key to establishing best practice for achieving sustainable energy systems. Implementation to be undertaken might include operational and architectural factors, with the need for newer policies and renewed investment strategies for producing, delivering, storing, and consuming electricity. Essentially new low carbon technologies are essential to the energy transition. Central to their adoption is to be able to integrate them into a working system. If regulatory policies do not change, it will constrain the growth of essential low carbon technologies in the electricity system, and this will make it difficult to maintain acceptable reliability and new standards of sustainability (MIT, 2011). There are two primary sources of knowledge about how island electricity systems respond to the introduction of new technologies and practices: the creation and interrogation of numerical models, and the empirical observation of on-the-ground implementations. The numerical models are mainly used for designing the system specifics and the policies whilst the empirical observations give hands-on experiences that can assist in informing the real-life occurrences for the system.

2.2 Modelling isolated systems

Analytical and modelling tools have aided the smart transition within isolated electricity system. Recent modelling tools such as HOMER and DER-CAM are useful and are geared towards the specific low-carbon electricity system aspects and optimisation problems. This approach is similar to the conventional TIMES MARKAL, WaSP and LEAP modelling tools that have long aided traditional electricity system planning. HOMER allows users to evaluate the economic and technical feasibility of a large number of technology options and to account for variations in technology costs and energy resource availability of hybrid renewable micro grids/remote island systems. DER-CAM is an economic and environmental modelling tool for customer distributed energy resources adoption. In addition, tools such as PLEXOS and the Islands Playbook energy transition initiative (ETI) have been adopted for assisting in selecting for the key elements in designing a comprehensive energy transition process.

In general, four main categories of planning models for the development and utilisation problems of modern and future electricity systems exist (Owlia and Dastkhan, 2012). These are:

i. econometric models such as linear programming;
ii. energy equilibrium models such as genetic algorithms;
iii. optimisation models using mathematical modelling techniques such as mixed-integer programming; and
iv. simulation models such as agent-based modelling.

These tools have proven useful for modelling different aspects of the electricity systems and aid with understanding the system planning and transitioning steps needed. Different aspects include capacity expansion investments and improving the decision making of the system such as grid balancing or energy policy analysis (Dyner, 1996; Lalor, 2005; Dimitrovski, Ford and Tomsovic, 2007; Ilic, Xie and Liu, 2013). In addition, modelling tools have been used extensively within the energy transition of isolated island systems. For example, Weisser (2004) examined the main economic and technological obstacles for incorporating renewables within small island systems, while Parness (2011), Pina, Silva and Ferrão (2012) and Ilic, Xie and Liu (2013) studied testbed systems for electricity grid balancing and unit commitment optimisation within remote grid systems. Other practical undertakings such as national energy roadmaps as done in IRENA, (2017) provides great value to the need for gaining insights from real-life implementations.

2.3 Studying real-world implementations

Many real-world implementations exist that exemplify different transition pathways and allow insight into the pursuit of smart energy solutions on islands. Low-carbon systems are continuing to evolve, alongside this a burgeoning literature considers effective policy and regulation, financial approaches and stakeholder engagement; this includes growth in smart energy approaches to island energy infrastructures (SmileGov, 2009; IEA, 2012; Ilic, Xie and Liu, 2013; Vallvé, 2013; IRENA, 2014a; Sawin, Seyboth and Sverrisson, 2016; Eurelectric, 2017). IRENA (2014) details over twenty-five low-carbon projects from islands and countries in the Pacific and Indian Oceans, the Mediterranean and the Caribbean. These projects illustrate many aspects of the smart energy transition to include projects for wind farms, solar farms and the use of energy efficiency and EVs for enhancing the energy security of the system and reducing their dependence on fossil fuels. According to the Islands Energy Program (2016), projects of this kind will create a blueprint that can be replicated in other isolated economies and possibly on other larger systems. Additionally, the development of micro-grid studies such as Jeju Island, South Korea and Hachinohe, Japan is noted. These micro-grid demonstration projects are examples of recent trialling of smart transition low-carbon electricity systems.

Low-carbon and smart grid projects are on the rise in continental Europe and in Europe's remote island territories (IEA, 2013; Sawin, Seyboth and Sverrisson, 2016; Eurelectric, 2017). According to Vallvé (2013), isolated island or remote areas can be an ideal testing grounds for mature low-carbon technologies. Since their indigenous low-carbon generation can be more cost effective in the long-term, and these potential technologies can also complement each other and can be matched in different ways to the electricity demand. This also implies that these systems are at the forefront of smart energy transitions with the innovative use of storage and load management techniques (Vallvé, 2013). The following section details an overview of many ongoing smart energy transition projects and agendas worldwide.

3. Existing smart energy island transitions

This section reviews experience to-date of smart energy island transitions. The range of smart energy transitions examined in this section illustrates the diversity of island contexts. The overview presented here gives an insight into the extent of the smart energy transition undertaken in each case study system. The main measure of distinction of these examples from interconnected systems is that they are all isolated in terms of their electricity infrastructure (not connected to a central electricity infrastructure) and not necessarily their geographic and/or economic remoteness. This means that these systems tend to have a reliance on diesel and the local energy economics are particularly influenced by the uncertainty of the global oil markets. Generally, peripheral and island systems are reliant on either fossil fuel imports or on subsea cable electrical interconnections, this makes them a good case for alternative routes to generation. The overview presented of these case studies is a non-exhaustive list of remote/isolated smart energy transition systems and projects within two categories: Europe (section 3.1), and Rest of the World (section 3.2). The global locations of these case studies/projects are shown in Figure 3.1, below.

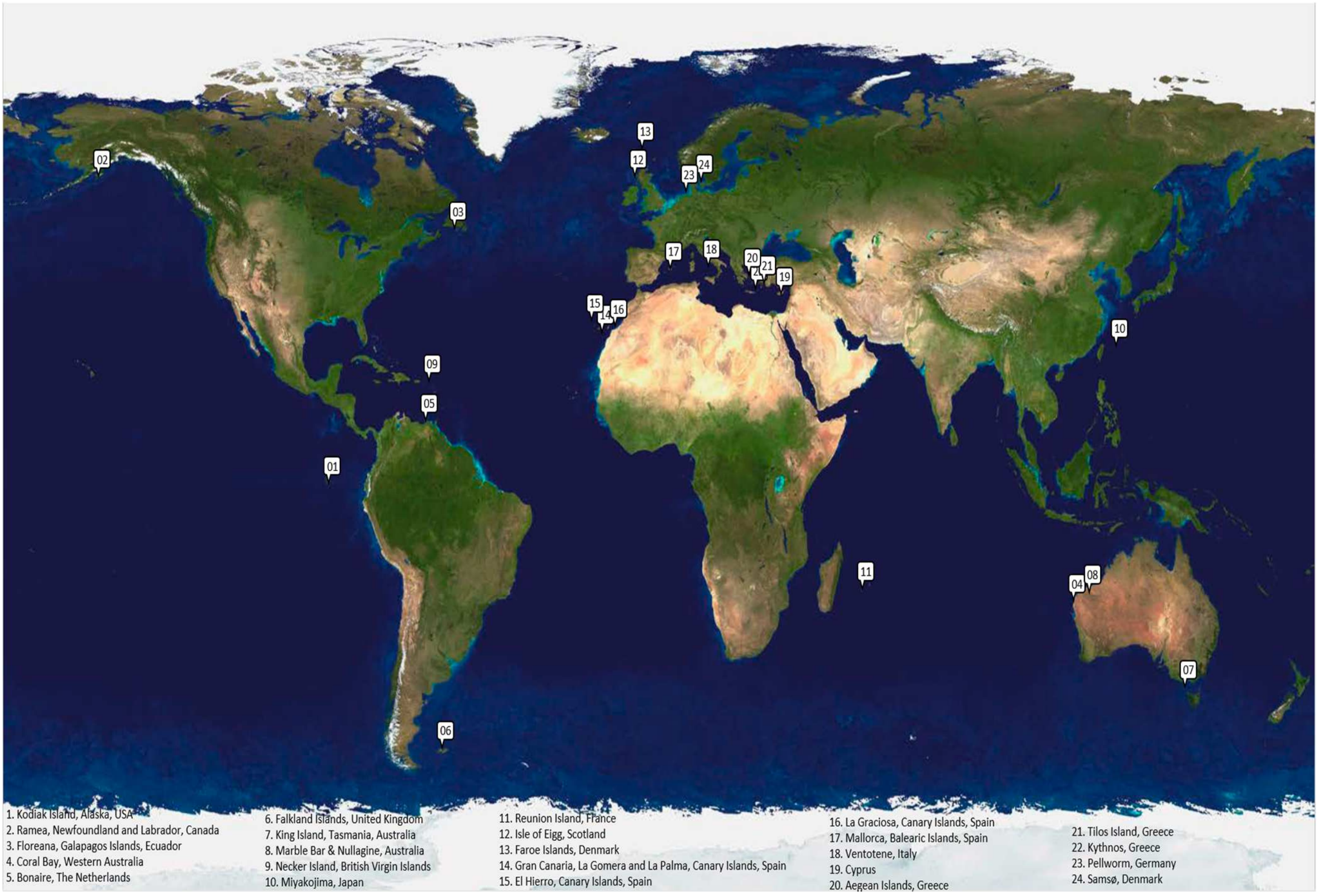

Figure 3.1: Geographical location of case studies

3.1 European islands

The European Union has sought to position itself as a leader in the transformation of its energy systems (European Commission, 2015), which is reflected in the level of 'smart' activity on the islands of Europe.

3.1.1 Isle of Eigg, Scotland

This case study with a population of 100 benefitted from a mainly renewables based connected grid rather than the existing individually operated diesel generators. The main idea was to pursue a more sustainable energy generation source than to rely on a fossil fuel grid in the future. A community led effort then sought to tap into abundant local renewable energy resources. This led to a system of wind, solar, hydro and diesel generation as opposed to connecting the island to the mainland grid of Scotland, which proved to be cost prohibitive. No subsea electrical connections existed before or during the transition. There is a prepaid usage system, which is capped at 5kW instantaneous peak demand power for small businesses and residents and at 10kW for large businesses. The residents do not normally exceed their prepaid weekly limit and hence this system allows for further cost savings as there is no need to excessively ramp up and down electricity generators. The total generating capacity of the whole system is approximately 184kW. (Bunker *et al.*, 2015; Green Eigg, 2010).

3.1.2 Faroe Islands, Denmark

The Faroe Islands, with a population of just over 49,000 inhabitants, have an energy transition objective to displace fossil-based generation with renewable sources. The Faroe Islands are electrically isolated from mainland Denmark. Fossil fuels met 95% of demand, with only a 4% share of renewable energy, in 2009. The strategy of the Faroe Islands involves developing a diversified agenda of projects and initiatives that seek to increase the use of wind, solar and hydro technology generation. An ambitious goal of 100% clean and carbon-free electricity production by 2030 is targeted together with the electrification of both the transport sector and the heating sector. Since 2015, the annual share of wind power was more than 18%, with instantaneous wind penetration levels exceeding 80% of the total load, from 4MW to over 18MW. An EU-funded project called TWENTIES PowerHub was critical for this transition aspect in which industrial consumers have been integrated in a load shedding system, to decouple loads like heat pumps, cold storages and freezing compressors when a local frequency deviation is experienced was trialled. In addition, a battery system was integrated with the wind farm. Other smart energy transition undertakings saw the local utility and local authority working together on different incentives to make electric vehicles and heat pumps more attractive to the inhabitants. A fast charging infrastructure for EVs (based on excess renewables at night time) has been set-up with strategically placed, island-wide public chargers. (BusinessGreen, 2012; IEA, 2012; Eurelectric, 2017).

3.1.3 Gran Canaria, La Gomera and La Palma, Canary Islands, Spain

These three islands of the Canary Islands archipelago were used under a single European project "stoRE" as case studies to demonstrate different technologies of energy storage. These islands as with most of the islands in this report are all electrically isolated from each other and to the mainland. The project described here sought to show the technical and economic feasibility of different levels of energy storage systems. The case study shows the integration and offered knowledge of the technologies in a real-world setting of these islands' electrical grids. Electrochemical Li-ion battery storage is used in Gran Canaria together with the local energy sources to test active power and providing inertia and participating in secondary regulation. Flywheel is used in La Gomera to provide inertia, active power for power regulation and for frequency stabilisation of renewable based island electricity grid. La Palma had ultra-capacitors installed to improve response in primary regulation and stability of the frequency of the grid, giving the isolated system more stability and quality of supply. (stoRE, 2011; Eurelectric, 2017)

3.1.4 El Hierro, Canary Islands, Spain

The smallest island of the Canary Islands Archipelago, led by a push from its 11,000 resident population, has driven the energy transition to make the system energy self-sufficient. This island is also electrically isolated. A pumped storage hydro and wind/diesel hybrid system provides the island with electricity from 100% renewable sources. The pumped hydro-wind aspect of the system transforms the intermittent wind into a controlled and constant electricity supply thereby maximising the use of this energy sources for readily integration into the system. This initiative is part of a wider program driven by public and private funding for sustainable development in which measures for increasing energy efficiency are explored and shifting from fuel to electric vehicles. The local government incentivises the purchase of electric vehicles whilst the local energy operator studies the development and implementation of electric vehicles (network of) charging stations. The installed generation capacity in El Hierro in 2015 was 35MW of which 12.7MW was fossil fuel based. (Bunker *et al.*, 2015; Eurelectric, 2017)

3.1.5 La Graciosa, Canary Islands, Spain

The local government of the 700 inhabitants of the La Graciosa Island has an objective to develop a renewable energy supply solution and to be self-sustainable in terms of efficient and stable energy. The main undertakings within the La Graciosa project that started in 2015 to aid the energy transition on the island have benefited from Spanish governmental and European funding. Key objectives within this renewables agenda lies with the control of the distributed generation to transform the network into a smart grid. Other aspects include development of an innovative hybrid system for multiservice storage. This is useful to manage the aggregate demand with autonomous user/client interactive control. The island of Graciosa have subsea electricity interconnection to the closest island to it, Lanzarote for importing needed power. Lanzarote is slightly larger and is electrically isolated from other islands and mainland Spain. (La Graciosa Project, 2015; Eurelectric, 2017)

3.1.6 Mallorca, Balearic Islands, Spain

This island of Mallorca with a population of over 850,000 has a very low penetration of renewables. Mallorca has an existing subsea interconnection commissioned in 2012 through a project called the Rómulo between mainland Spain, Mallorca and then onto to Ibiza. Some recent Spanish and European funding has initiated a change from this high reliance on fossil fuels with small steps. An existing energy transition project called “ecaR Project” centred on the electrification of the transport sector has already started. It aims to create six fast charging points that are strategically placed to form the first electric vehicles charging network for the island. Use is made of a smartphone application that allows users to find the charging points and useful related information (nearest location points, reservations, finding the best route to reach them and calculating travelling time) to charge their electric vehicles. (Eurelectric, 2017; REE, 2018)

3.1.7 Ventotene, Italy

This island is located in the Tyrrhenian Sea off Naples. It has a permanent resident population of about 780 and struggles to cope with an the annual influx of tourists, which gives seasonal swings in electricity demand. Ventotene has no subsea interconnection to the mainland grid and depends solely on four diesel generators, each with a nameplate capacity of 480kW. The island's shift to renewables and the smart energy transition shows as a growing deployment of rooftop photovoltaic. The utility installed a lithium-ion batteries storage system project of 300kW/600kWh to aid with the integration of solar power generation into the island. Funding for this project was sourced from the European Investment Bank. This energy transition project represents a best practice in the way that storage system with storage fast dynamics (grid dynamics are addressed by the batteries) is coupled to diesel generators. The island also has in place preparatory work for future smart applications, such as electric vehicles charging stations. (Eurelectric, 2017)

3.1.8 Cyprus

Cyprus is one of the largest European islands engaged in a smart energy transition terms of population, at over 1.1 million people. As a Member State of the European Union it has a national target for renewable deployment across all energy consumption of 13%. Current renewable energy penetration is around 8.5%, which includes wind, biomass and residential and large-scale solar installations with a national roadmap aiming for higher penetration. To assist further development and maximise renewables penetration the local utility is engaged in two European funded research and development projects: Green+ and SmartPV. The first of these projects aim to manage and optimise the distributed renewable generation of low voltage network (20 MW) and medium voltage network (50 MW) installed solar. The other project emphasises smart net metering for the promotion and cost-efficient solar grid-integration. Additionally, the island has an existing electric vehicle charging service offered and funded by the local utility as a pilot project called E-Charge. The impact of electric vehicles charging on the distribution system is observed and it helps to promote electrification of the transportation sector on the island. Other innovative renewables venture projects funded by the European Commission, European Investment Bank and other member states are the Helios Power Project and EOS Green Energy Project. Currently, Cyprus do not have subsea cabling to any mainland but signed a deal in 2016 for a possible interconnection to Egypt. (CyprusProfile, 2017; Eurelectric, 2017; SmartPV, 2017)

3.1.9 Aegean Islands, Greece

The Greek islands of Kythnos, Milos, Santorini, Lesvos and Lemnos are the focus of this case study. These islands, with a combined population of 150,000 inhabitants are electrically isolated from each other and the mainland. The smart energy transition of these Aegean islands entails promoting smart grids in these islands to improve the quality of electricity provided and also to increase the penetration of renewables and allow more flexible management of the demand loads. The islands are part of DAFNI – the Network of Sustainable Greek Islands consortium that provides technical assistance and collaborative learning expertise for island transitions within the region. The European Investment Bank funded the project at a cost of over 52 million euros. This energy transition case study included a wide range of smart technologies such as Energy Management Systems (EMS), Market Management Systems (MMS), Automated Metering Infrastructure, electric vehicles charging stations communication for EV load management, energy efficiency in street lighting with smart metering for the remote control of the lights. Additional aspects pursued for the maximisation of renewables penetration in these island systems are interventions in the regulatory and legal landscape in order to move ahead with the tendering and the investment within the island. (SmileGov, 2009; Eurelectric, 2017)

3.1.10 Tilos Island, Greece

The island of Tilos has a resident population of 500 and meets its electricity needs through an unreliable subsea electrical interconnection to another island, Kos, which operates a diesel-oil power station. This island however has many long-lasting blackouts because of undersea cable faults. The energy transition within this island is pursued within the scope of the TILOS project, which aims to facilitate increased renewable energy sources under the optimum exploitation of energy storage assets using a prototype battery system based on FIAMM NaNiCl2 batteries. This is provided with an optimum smart grid control system that copes with supporting multiple tasks of energy management, maximisation of renewables penetration, grid stability and ancillary services to the main grid of Kos island. The unique aspect of this transition is that the smaller island is connected to the larger island where the battery system will support both stand-alone and the grid connected operation. Different operation strategies are tested to define the optimum system integration. Also included within this approach to smart energy transition is the formation of novel business models for the market diffusion of the integrated battery solution, which will also engage also the local public. (Eurelectric, 2017; TILOS, 2017)

3.1.11 Kythnos, Greece

Kythnos is a Greek island with a population of 1,632 that has a long history of sustainable energy applications dating back to 1982 with Europe's first wind farm. The island has a range of renewable energy technologies such as a solar power plant coupled with batteries and a hybrid wind turbine, battery storage and automatic control system that are obsolete. The only working generation systems from these early projects are small standalone solar installations. The current installed generation capacity within the island is 4.97 MW with a peak consumption of 2.7 MW. The energy transition vision of the island is to move towards a smart and sustainable development of the island to include the touristic effects on seasonal electricity demand season. One project that aids this transition with the island as a demonstration site is the WiseGRID project, which aims for the deployment of new, innovative and smart technologies that will help make the electricity grid safer, smarter and more efficient. An integrated management system will be demonstrated that combines electric vehicles, demand response (public buildings), critical infrastructure (port, desalination unit) and grid management for a more efficient and economic operation of the system that is customer focused. (Eurelectric, 2017; WISEGRID, 2018)

3.1.12 Pellworm, Germany

Pellworm is located in the north of mainland Germany. This island with a population of around 1,200 has a pioneered the utilization of renewable energy since the early 1980's. Pellworm is not electrically isolated and has a subsea cable to the mainland electricity grid of Germany. Wind has been shown to have the greatest potential in the island wth over 6MW of capacity installed. A broad basis of renewable sources for the smart energy transition is seen in Pellworm with the use of biomass, PV, heat pumps, solar thermal, biogas and increased energy efficiency. PV and wind-hybrid energy systems exists with a view of having energy storage batteries for excess wind and solar energy. The island produces about three times the amount of electricity as needed on average and hence supplies the mainland with the excess electricity. (ISRR, 2009a)

3.1.13 Samsø, Denmark

Samsø is a Danish island with a population of about 4300 inhabitants. The island was chosen to become a model of a renewable energy community within the scope of the Danish Action Plan, Energy 21 (Danish Energy Agency, 1996). Samsø moved from a 100% dependency on fossil fuels in 1997 to achieving self-sufficiency from renewable energy by 2003. The European Union funded ALTENER project was instrumental in aiding the initial transition process by providing subsidies. The island is not electrically isolated since some of the wind farms for the island are linked to the mainland national grid, so they can both export and import energy from the grid. Hence, the island can be 100% renewables symbolically and not necessarily using renewables all of the time. Twenty-one wind turbines operate on and around the island, both offshore and onshore, with an installed capacity of over 23MW. There are also four district heating plants on the island that are supplied from solar panels and wood chip-fired boiler and straw boilers. Samsø also has a strong emphasis on capacity building of the community and features an Energy Academy that perform research and gives community advice on renewable energy. (ISRR, 2009b)

3.2 Rest of the World

The remaining examples in this review are islands from outside Europe.

3.2.1 Kodiak Island, Alaska, USA

A case study that focused on the successful implementation of renewable energy. It includes a hybrid wind and diesel generation system completed in the 2009 together with an existing hydropower dam. A 3MW (2 MWh) lead-acid battery contributes to the stability of the system, and the operators recently added two 1 MW flywheel systems for added system stability. The focus of this island system transition is to reduce diesel generation and achieve 100% renewable generation; it attained around 98% as of 2012. The island has a population of 13,000 with the installed electricity generation capacity of 75MW. (IEA, 2012; Bunker *et al.*, 2015)

3.2.2 Ramea, Newfoundland and Labrador, Canada

The Ramea Island has a population of 526 inhabitants and is electrically isolated from the North American grid system. The island served as a case study of an innovative hybrid system that makes use of wind and hydrogen storage in combination with diesel generators (three different diesel units) to meet electrical demand. This lead to over 700kW of wind and 250kW of hydrogen storage generation. The energy transition demonstration focused on the attainment of reduced fossil generation whilst increasing the share of renewables within the system. A huge collaborative effort of local and private funding sources were key to this energy transition process. (Vallvé, 2013; NRC, 2015)

3.2.3 Floreana, Galapagos Islands, Ecuador

This case study island is the smallest in the Galapagos Archipelago, with a population of 200 and do not have any subsea electrical interconnection to the neighbouring islands and mainland. The energy transition is targeted on the reduction in energy usage and diesel generation. A push for renewables has been widely adopted with the implementation of solar and diesel hybrid project. This project included a multi-use solar grid for the community use and five standalone solar facilities for farmhouses outside of the main village. Energy efficiency was encouraged by providing rebates for energy efficient appliance upgrades. This transition seeks to reduce the electricity demand whilst increasing to appropriate amounts of installed renewables. (IEA, 2012)

3.2.4 Coral Bay, Western Australia

This case study represents a very small resident population of 140 but with a daily tourist visit of about 3600. The installed generation capacity of the island is 2.92MW with a peak demand of 0.6MW and no subsea electrical connections exists. The energy transition started in 2007 and is mainly focused on increasing the share of renewables within the system. A wind and diesel hybrid system is used to meet the electricity demand. To aid with the balancing of the intermittent wind resource low-load diesel generators and a 500 kW flywheel as used for this system. This allows the wind turbines to contribute on average 40-60% of the electricity demand, although at times they can contribute up to 90%. This transition also had some built-in resilience with “hurricane-proof wind turbines” that can be stored away (tilted and lowered to the ground) in the event of dangerous weather. (IEA, 2012; Bunker *et al.*, 2015)

3.2.5 Bonaire, The Netherlands

The circumstances of this island system, which has a population of 16,541, played an important part in its energy transition. After a fire in 2004 destroyed the only power plant on the island a more sustainable means of electricity production was pursued. This includes a move towards 100% renewable electricity supply. The new electricity system is designed around renewables. It consists of a combination of wind turbines, a 3MW (100kwh) battery and 14MW of installed diesel (mainly needed for the frequency balancing of the grid) hybrid system - total installed generation capacity is 25MW. The island is electrically isolated with almost half of its annual electricity coming from wind power. (Bunker *et al.*, 2015)

3.2.6 Falkland Islands, United Kingdom

The Falkland Island has a population of 3,398 and is electrically isolated from the closest mainland South America. This island system is heavily endowed with wind resource potential. The transition strategy is to harness the vast local energy potential and displace the current diesel generation. Solar and hydro assessments and experiments were conducted however the planners stuck to the use of wind as the main renewable generation source. In addition, the system includes a small flywheel for stability issues and hence increase the efficiency of the hybrid wind-diesel system. The current installed capacity within the island stands at 8.58MW of which 1.98MW is wind. The wind farms have reduced diesel fuel use by 1.4 million litres per year saving the customers’ on their electricity bills. (IEA, 2012; Bunker *et al.*, 2015)

3.2.7 King Island, Tasmania, Australia

This island system with a population of 1800 has put in place a renewable energy integration project as an overarching guiding agenda for its transition from diesel to renewables. The island is electrically isolated with a total installed generation capacity of 8.84MW. The electricity generation within this system includes wind, diesel, solar and a 3MW (1.5 MWh) battery storage. In addition, two 1 MW flywheels are used to work with a dynamic resistor to allow the system to run without diesel generators for extended period of the day on many occasions, this first occurred in 2013. Smart meters have been deployed to residents for PV generation monitoring and to record real-time customer energy use. This energy transition reduced the CO_2 emissions of the system while improving the reliability and overall power quality of the island electricity system. (Hydro Tasmania, 2014; Bunker *et al.*, 2015)

3.2.8 Marble Bar & Nullagine, Australia

This case study represents two micro grid communities in which the energy transition was motivated by the need to show the incorporation of renewable resources as a test case for the local utility operator to show what is possible. The communities have a population of 600 persons. A hybrid system of solar PV, diesel generators and a kinetic flywheel installation is used to enable the micro grid to operate on very high penetrations of the available solar resources. The installed generation capacity is 2.75MW with 508kW of PV generation. Energy efficiency audits were also conducted for the residents as the solar systems were rolled out in the various communities. (Bunker *et al.*, 2015)

3.2.9 Necker Island, British Virgin Islands

This privately-owned island of 60 inhabitants is used as a test bed for an energy transition. The system has a combination of solar, wind and diesel generation (2.16MW in total generation capacity) and benefits from the retrofitting of existing buildings with increasingly efficient AC units and upgrading insulation of many of the buildings while adding smart controls. For this case study energy transition, a systematic implementation approach is used for the various renewable resources, energy storage, and controls. This is done to aid with the assessment and validation of the impact of each technology before moving on to the next phase of the transition. (Bunker *et al.*, 2015)

3.2.10 Miyakojima, Japan

Miyakojima has a population of 54,908 and is located in the Philippine Sea off the Japanese coast. It is the largest of the Miyako islands. This island's is electrically isolated and the energy transition has focused on expanding the use of renewable energy sources, starting in the early 1990s. There is wide adoption of photovoltaic systems and a number of wind turbines (1800kW). In addition, efforts are being made to increase the use of ethanol to fuel a portion of the transport fleet. The island has also started using large sodium-sulfur (NaS) batteries (4MW), as well as smaller residential scale lithium-ion (Li-ion) batteries to enhance grid stability. This energy transition is operator driven and seeks to target reduced electricity prices whilst contributing to carbon emissions reductions. (IEA, 2012)

3.2.11 Reunion Island, France

Reunion Island is located in the southern part of the Indian Ocean and has a population of over 800,000. It is an overseas department of France. The island is electrically isolated and has a few gas turbines and coal power plants in addition to diesel generation plants. This island is used as a testing laboratory for a wide range of renewables deployment and demonstration projects, as well as the large-scale use of electric vehicles. The range of transition projects includes ocean and wave power, solar PV, grid-scale storage and small-to-medium scale hydro. In addition, a few projects such as the PEGASE project were completed for testing ways to improve the existing renewable system. These involve the use of advanced grid and load management technologies, including residential battery storage. In addition, using technologies to perform day-ahead and intra-day forecasting for two solar farms to aid in the smoothing of intermittent energy. Smart management of the storage and the generation of intermittent renewables is carried out. These recent projects have greatly improved the smart energy transition of this island, which includes meeting the French government goal of 50% renewables of the island's electricity needs by 2020 and a further goal of 100% of all energy use by 2030. (Eurelectric, 2017)

3.3 Discussion of real-world cases

The insights gained from the case-studies presented in the previous section can be grouped into four broad categories as seen throughout the smart energy transition literature and proposed in the ICE project; technological, policy and sustainable development; financial and economics; and stakeholder engagement.

3.3.1 Technological

The specific technological characteristics of ongoing smart energy transitions within isolated territories tend to be unique to these systems, but study of approaches to selecting technology mixes, the route to their deployment and how they meet energy needs can aid in better understanding the devising of effective strategy for smart energy transition. Some of the key technical differences between an isolated/island system and one which is not, are the comparatively small electricity grid size, the shape of the electricity load due to daily and seasonal demand variability and the centralised and heavily diesel fuel dependent characteristics of existing electricity (IEA, 2012).

As observed from the case studies highlighted before, high penetrations of renewable electricity are considered as achievable goals, adopted and pursued. However, a low-penetration of renewables within these systems are typically installed before attempting higher levels of penetration. Small-scale, high-penetration system can be pilots for larger-scale high-penetration systems and for testing the viability of these technologies (IEA, 2012; Vallvé, 2013; ETI, 2017). Initially low penetration of renewables into systems allow simpler design and operation and once proven can serve as jumping off points for further deployment. In most cases these smaller systems require little or no additional equipment to facilitate a reliable system. As the penetration level increases, the necessary equipment and design challenges needed for the smart energy transition system increases.

Further observations from the case study systems indicates that the various renewables technologies can complement each other and can be matched in diverse ways to the energy demand as the smart energy transition is achieved. According to the IEA (2012), hybrid electricity systems can also leverage the strengths of different technologies to provide lowest cost power generation. Added to this, if the pursuit of 100% renewables penetration are not technically or economically feasible, it would be reasonable to use hybrid electricity systems to maximise a renewable energy penetration. This will give confidence that the level of renewable penetration is within the goals of the smart energy transition for using the locally available energy resources in meeting the environmental concerns. This would occur within the technical limitations of the system to provide reliable energy for the locals.

Energy storage is playing an increasingly significant role within these hybrid energy systems. Hirsch *et al.* (2015) postulate the use of lead-acid batteries – a readily available and mature technology which is familiar to locals and which can aid system management with high penetration of variable and non-dispatchable solar and wind generation. According to the authors, a combination of renewables, storage, and diesel generator that are carefully sized and integrated can yield the lowest-cost solution for the generation of sustainable electricity. It was seen that small-scale storage for systems of up to 10 MW installations normally use lead-acid batteries as the chosen storage technology, though other storage alternatives are increasingly being brought to market. Additionally, the need for a diesel generator was observed only with the larger electricity systems that need grid balancing in which the use of a fly-wheel or other low-carbon solution were not feasible. Pumped hydro existed within a few transitions systems, were this was both technically feasible and economically supportable within the needs of these systems. Isolated systems are at the forefront of innovative use of storage within the smart energy transition.

Diesel generation may still be needed in some isolated systems as an energy transition progresses. In such cases, there will be a need for improved controls to ensure reliability and to reduce the excessive ramp up and down of the diesel generators. In addition, the full understanding of the installed renewables availability and capacity factors should be considered for proper system design and integration of these renewables into the existing grid. Grid reliability may also be able to be supported with demand side response and other demand management resources within the system such as the shipping port desalination unit of the Kythnos case study. Other standard mechanisms such as load shedding and remote monitoring and system control can provide critical information to manage the system. For the efficient integration of variable renewables it is imperative for the system operators and planners to perform the necessary power system models such as load-flow, stability, short-circuit, protection and coordination studies (IEA, 2012).

A critical area of importance is the operations and maintenance of the isolated electricity grid system. According to (Vallvé (2013), the proper operation and maintenance over time of the developed renewable-based energy systems is a significant barrier to the smart and sustainable energy development in isolated areas. It is noted that renewables systems installed in isolated areas suffer because they were not properly maintained and the availability of spare parts and locally trained technicians/experts in the case of failures.

Other technological insights gained for the smart energy transition are in respect of electric vehicles and their relationship to the transportation sector within these isolated communities. It is demonstrated in a few of the reported case studies that a switch to electric vehicles could support grid integration in which electric vehicles can absorb excess renewable generation. The added potential, to supply electricity back to the grid, while often a feature of suggested transition strategies, was not observed in any of the existing smart energy transition projects, as it is not yet technically feasible. It was also considered that the use of hydrogen in which excess energy from renewables could be stored in the form of hydrogen and re-used during periods of non-production and/or for stabilising the grid operation is a useful technical innovation of the smart energy transition. Advances in solar thermal heating can include a wide range of applications including space heating, industrial process heating, and to drive absorption cooling is needed but so far only heating of domestic hot water exists in most of the islands. The use of heat pumps was mainly seen in the isolated islands that exist in the winter locations such as in northern Europe.

Key technological issues within the smart energy transition focuses around developing an infrastructure integration plan and creating an operations and maintenance strategy. Planning in isolated electricity systems should often be more specific, rigorous and transparent than the current practice within larger interconnected systems. This is due to the specific context and small-scale of the systems, which increases the need to match the energy generation sources with demand and the need to utilise resources such as storage, demand response, controls, smart meters and other smart transition enabling technologies in an integrated and sophisticated way as renewables penetration levels increases (IEA, 2012). The technological characteristics as observed within this section provide useful lessons for smart energy transitions. Making appropriate technological selection is key to ensuring that transitions occur.

3.3.2 Sustainable development policy

The smart energy transition with the use of renewables in isolated areas provides peripheral communities and/or remote systems with an opportunity to demonstrate leadership in low-carbon technologies and integration. This leadership is not only important for the local community resilience, but also to build worldwide expertise in high-penetration renewables and smart energy systems (IEA, 2012; Eurelectric, 2017). On the other hand, given the geographic isolation of these transitioning systems together with the small size of the smart energy projects, it can be challenging for investors and project developers to promote and create capacity building and training programs in a cost-effective manner.

It is observed that a framework of sustainability, as a policy instrument, is needed between all stakeholders. This framework is key to the Government and utility owners, and should be simple and focused for the aims of the transition. This can be achieved with an independent regulatory body with a local understanding of the current system and strategies needed. Essentially, a system specific range of national policies need to be adapted to promote renewables, electric vehicles, energy storage, demand management and the resulting sustainable development through the energy transition in isolated areas. New institutions and regulatory environments would also be needed as shown in some of the case studies such as Greece's Aegean Islands, which were useful for attracting investments within the isolated grid system. Alternative tariff structures can also be developed that are specific to remote areas (Vallvé, 2013).

Renewables play a key role in the smart energy transition and tend to be an imperative part of the broader sustainability portfolio of the system as it leads to "greener" communities, with less carbon emissions. An important lesson from isolated systems is that renewables can achieve the environmental goals of these remote areas and show that these smaller and remote areas can play their part in climate change mitigation. However, though renewable energy technologies tend to have lower environmental impact than fossil generation, they can still negatively impact the local environment (Bickel *et al.*, 2003). Hence, site-specific environmental due diligence should be carried out for the transitioning systems with the understanding that different renewable technologies may pose different risks. According to IEA (2012), most isolated electricity systems are located in environmentally, sensitive and unique that require special consideration such as protecting biodiversity.

Within the policy framework and the sustainable goals of the isolated systems, the consideration of the resilience of the system must be considered. Extreme weather events must also be contemplated in the process of installing renewables such as undertaken by the planners in Coral Bay, Western Australia in installing "hurricane-proof wind turbines". Additionally, many of the environmental concerns are now better understood due to the work of governments and advocates and a resulting broadening of the literature. Examples of this includes wind turbines not being installed near to the nesting grounds for endangered bird populations or small-hydro projects being planned so as to not affect aquatic ecosystems (IEA, 2012).

3.3.3 Financial and economic

Smart energy transitions in isolated island systems carries with it an inherent drawback that applies within a broader financial and economic context and consistent with conventional wisdom within the energy industry. This drawback as observed within most case study systems is that smaller and more variable (less dispatchable) renewables hybrid systems are economically less attractive than larger scale systems. It has been observed however, that with smart energy transitions in isolated systems, a useful argument is that key consideration can be given for the marginal generation cost of new diesel generation vs the marginal generation cost of renewables (Eurelectric, 2012). It can also be highlighted that renewables and smart energy solutions can provide deferred investments within the electricity systems, thereby reducing the broader financial and economic impacts (Pina, Silva and Ferrão, 2012; Eurelectric, 2017; Matthew, 2017). Such deferred investments can be achieved with the use of renewables or other smart solutions such as electric vehicles for load matching to lower demand peaks/raise demand troughs within the system. It is however important to note that in terms of up-front capital costs, the use of renewables is disadvantageous compared to conventional diesel generation especially within remote systems. Added to this drawback is the fact that most isolated electricity systems do not command an economy of scale that can facilitate markets for energy services and do not have any market-type responses to renewable technologies reaching "grid parity" (although this has also yet to emerge in larger interconnected systems). However, due to the higher cost of imported diesel to isolated systems renewables can prove to be have a comparative unit cost to diesel generation in the longer-term.

When considering the benefits of transitioning to a smart energy system, investors normally gauge an investment's rate of return and this is also the case whilst planning smart energy transition projects. It was observed by Hirsch et al. (2015) that a potential alternative investment approach for particularly small isolated systems exists. This approach includes a strategy in which the private investor is not looking for a high percentage return such as 12%, but rather, the local utility needs to cost-effectively displace diesel fuel, so a lesser return on investment (ROI) can be agreed for that added benefit. In other words, a "business case" model may require an alternative mix of private and public investments with the focus on cost savings from diesel displacement as compared to the investment's internal rate of return. As in the case of the Faroe Islands, the wind projects on the island were partly financed by issuing shares to allow local residents and other mainland Danish citizens to invest directly into the project (IEA, 2012). Residents agreed to a lower ROI as they know that their investment will reduce the island's dependence on diesel and increase its energy security.

The case studies of smart energy transitions point to pilot and demonstration projects often being used to initiate the transition, enabling application of national and international research and development budgets. Public funds can be used to leverage private funds, with this justified on the grounds of the public interest in securing reliable, economic power supply and addressing carbon and other emissions. When public stakeholders underwrite the upfront costs, private sector stakeholders have been able to make valuable investments in remote areas (Eurelectric, 2017). Designing innovative cooperation mechanisms and financing instruments should be an integral part of the smart transition process. Furthermore, there is potential for outside funding agencies such as the global environment facility to play a key role in providing gap funding in the most financially challenged systems.

Additionally, development risk (community buy-in, obtaining permits etc.) related to project financing can create a substantial barrier to smart energy systems in isolated areas. The associated costs are not just limited to the actual system cost but also to logistics, permitting and other challenges specific to the isolated system for installing items such as electric vehicles charging networks, wind farms, solar systems and energy storage. Hence, the total financing costs play a critical role in determining the initial affordability, competitiveness and the benefits of the transitioned system. Examples include project aggregation to ensure economies of scale and cost reduction and benchmarking energy costs based on island specificities (Eurelectric, 2017).

Separate to the financing characteristics of the smart energy transition in isolated systems are the added benefits to the local economy. Smart energy solutions can have a direct employment impact in local communities for construction, data management and on-going operation and maintenance. Renewable installations can have indirect impacts by providing additional revenues to local governments via sales tax, property tax, import duties and/or income taxes on smart energy facilities., thereby keeping more money in the local economy. This type of activity can also have positive benefits to the local acceptability of new technologies and there is considerable evidence that perception of benefits accruing locally can enhance the local perception of renewables. The key issues highlight that the smart energy transition within isolated communities should be viewed within the broader context of the system plan and with the implications of both economic challenges and benefits fully considered.

3.3.4 Stakeholder engagement

Stakeholder engagement has come to be seen as a key element for the smart energy transition. The process of engaging with stakeholders is not considered to be a very rigid one, with developers needing to be responsive to the varying needs of different stakeholder groups but should as a minimum include the establishment of a framework of shared aims and goals that is acceptable to all of the major players within the local smart energy transition. According to the ETI (2017), along with the necessary electricity grid integration assessments, local site and community-specific sustainability strategies are often essential for the long-term success of the transition. Stakeholder engagement strategies have been developed as key elements of many of the case studies. These include assessing the overall aims and objectives of the smart energy transition with possible ownership structures, identification of a “project champion” to act to communicate both ways between project developers and community and the establishment of a viable business entity to conduct ongoing operations, maintenance, troubleshooting and community education and outreach. A wide range of interested parties can be involved as discrete stakeholder bodies, from individual community members to community-based NGOs to local government, a business cooperative and the local utility. Some of these will be essential, while others can be desirable and can ease the formation of the impetus necessary to ensure that the transition goes ahead.

A key aspect of stakeholder engagement that emerges from the literature is that policymakers and developers must carefully consider how local communities will receive smart energy systems and structure the appropriate community engagement and capacity building to suit this. It can also be highlighted that there is a need for local expertise to be developed and utilised to support the new systems and operations. Many of the projects are justified on the basis that they replace expensive diesel generation with a more secure and free in the long-term electricity supply, thus providing lower priced electricity. The case studies of Kythnos and the Aegean Islands in Greece, the Isle of Eigg, Scotland and Denmark's Faroe Islands provide community value with electric vehicle charging and participation in the funding of some of the projects. Moreover, the local private sector should be engaged to support smart energy system development particularly in remote systems. the potential for developing markets for eco-tourists who are mainly interested in environmental sustainability issues can also provide a way to encourage local stakeholder buy-in and lead to 'green island' branding as a selling point to support tourism.

Added to the individualised stakeholder engagements from the case studies it was observed that there are many clusters of island communities teaming-up to tackle the smart energy transition. For example, SmileGov (2009) seeks to bring together the forces of many European islands under a general political commitment for the individual island authorities/key stakeholders to promote sustainable energy solutions within the EU 2020 strategy directives. It aims to establish study groups whose objective is to identify priority-training needs for each participating island and encourage other islands to join the wider effort. Wider stakeholder engagement can be aided with such measures, however, the specific context of each remote system must be explored within the scopes and aims of the smart energy transition.

A main lesson, imperative to a smart energy transition is that a bottom-up approach with citizens' involvement is a key step right from the beginning.

4. Peripheral territories' smart transition: opportunities, challenges and best practices

Smart transitions present several opportunities and challenges for communities, businesses and policymakers. The following sections present a condensed view of the factors that may drive a community's decision to pursue a smart transition as well as the difficulties that must be overcome to realise such an aspiration. Section 4.1 enumerates the opportunities, section 4.2 the challenges while 4.3 distils these insights into a series of 'best practices'.

4.1 Opportunities

The differences and specific context of the various isolated areas requires different smart energy policy approaches and renewable energy technology solutions. Some of the big picture transferrable opportunities from past and ongoing isolated systems smart energy transition projects as emulated from this literature review follows.

1. Remote areas can be ideal testing grounds for technologies or applications that are already mature or nearing that stage. These systems have an abundance of local sustainable energy resources and can be a clean source of data from the technology experiences.

2. The isolated systems endowed with renewables give huge potential for reduced electricity costs. This is mainly because renewable technologies are experiencing declining cost with increased savings potential. Compared to the cost of providing a subsea interconnection where feasible and the high price of diesel.

3. Energy storage, energy efficiency measures and smart controls are increasingly more important for the smart energy transition. Isolated systems are at the forefront of the innovative use of storage and other load management techniques.

4. Community engagement is seen as a key component of success for the smart energy transition. NGOs and other external governmental organisations can play a key financing role for meeting investment shortfalls.

5. Smart energy transition in isolated systems enhances the long-term system resiliency, provides a sustainable energy source and can act as a modular solution for larger systems and for replication within other isolated systems.

4.2 Challenges

An issue inherent to isolated electricity systems are their relatively small size and often-remote location. By extension, this can impose difficult conditions on their electricity markets. Further, grid balancing can be more difficult due to the relative limited options that the limited scope of the system traditionally offers. This offers challenges as well as the potential for new and more innovative approaches. The following are some of the big picture transferrable challenges from past and ongoing isolated systems smart energy transition projects suggested by this literature review.

1. There is a lack of supporting legal and regulatory frameworks targeted towards the specific context of isolated electricity systems. This might include policy and frameworks for assisting with project planning and implementation and for designing appropriate incentives. Further, some countries may have commitments to equitable cost structures across all consumers that provide an additional area for consideration in determining the options for the transition to a smart, renewable system. France is a case where this may be an issue.

2. Investors may experience a lack of access to capital due to the small scale of projects, often with large payback time. The ability of smart energy transitions to finance projects without some kind of public sector involvement may be limited. This may be balanced by high existing costs however, which impact on the local economics of electricity supply.

3. There is an underlying issue with grid stability related to the small network scale and with relatively high deployment of intermittent renewable sources. There is hence a need to determine the appropriate level of renewables penetration for the specific isolated electricity system and to match this with more active network management tools as balancing challenges become demanding.

4. The local utility companies need new business models to include prioritisation of energy efficiency, and in addition finding other innovative revenue streams for these companies to aid the smart energy transition.

5. The lack of technical expertise and the training of local experts for the smart energy technologies within the local community will tend to be initially non-existent. Making training available for local personnel and providing related funding may be needed for these systems but this can also provide a visual representation of local socio-economic benefit stemming from the new system.

6. Mitigating risks within the new system is a major concern. It is believed by key energy stakeholders that targeted risk mitigation can substantially improve the attractiveness of isolated smart energy projects. Developmental risk linked to the refusal of the community or utility company to support the transition can significantly hinder the smart energy transition.

7. If it exists, the continued subsidisation of fossil energy sources represents one of the chief barriers to the wider adoption of sustainable energy sources in isolated systems. The cost of fossil fuels is prohibitive to the economic development of isolated territories. With a dependence on fossil fuels for electricity, these systems will be left with a much more costly and unsecure electricity generation source.

4.3 Best practices

In the table below, we outline a series of best practices that flow from the preceding analysis and highlight the relevance to the specific case of the ICE project.

Best practice	Rationale	Relevance to ICE	Practical considerations
Adopt new technologies	The particular challenges of island energy systems mean that novel and new technologies will be especially valuable.	Ushant, as a completely isolated system may benefit from battery storage technology.	The appropriate sizing of batteries together with the best hybrid generation sources options needs attention.
Engage local communities	Creating a new form of energy system cannot be driven from the top-down. It is vital that not only is community engagement seen as a tool for removing resistance to change but that the nature, timing and extent of change is the result of real discussions among system participants.	The local community is heavily invested in the activities taking place on the island. They will be integral in making things happen on the island	A bottom-up approach is key, with ongoing consultations at every stage of the energy transition

Involve local enterprise	The long-term economic benefits of the transition may be associated with ongoing provision of goods and services by island companies.	This can maximise financial opportunities for existing local companies and create jobs, which can raise acceptability.	Gauging the investor's required rate of return and bridging the development risks (community buy-in, obtaining permits etc.) encountered
Invest in skills and capacity	In many small communities, the capacity and skills required to undertake an energy system transition are very limited. Strategic decisions about the skills to be fostered may build long-term economic resilience.	There is a lack of on-island learning institutions and expertise. The main energy company's key experts are based on mainland France.	Training the local population to deal with issues of the smart transition. Innovative and collaborative capacity building and retention is needed.
Consider alternative business models	It may be the case that community-led or locally-owned energy ventures are better suited to island contexts than traditional utility business models.	A push to develop pilot projects can attract seed funding which can later be expanded at demonstration sites.	Public-private partnerships can give huge dividends in this instance.
Play to your strengths but be realistic about supply options	Many islands have impressive energy resources, but these are often concentrated in one or two resources, limiting the ability to rely solely on these resources.	There are lots of wind resources in Ushant, however due to strict conservation issues this resource can be partly harnessed. Other technologies such as solar will have to be the main player in this transition.	A small-scale, high-penetration system can give a good basis for larger-scale high-penetration systems and for testing the viability and acceptance of the available technologies
Use energy wisely	Reducing overall demand peaks as well as making energy demand more responsive to resource availability may reduce the cost of generation and distribution as well as actively contributing to system reliability.	An active role for the consumer can defer expensive generation investments and can also lead to a more reliable grid with less differences in the peaks and trough of the demand cycle.	Usage of smart technologies to influence the behaviour of local consumers with incentives to reduce demand.

Table 4.1: Series of best practices from preceding analysis

4.4 Conclusion

This review highlights the lessons learnt and best practices observed from past and ongoing smart energy transitions within isolated territories. An overview of the various types of methods such as analytical, modelling and real-world implementations that can be used for understanding smart energy transitions is highlighted. The many case studies that have been and are currently being used for smart energy transitions in remote areas are key to gaining insights into the best practices that can be adopted and identifying the most important lessons from the transition process.

Key lessons and best practices have been categorised in four key areas: technological; financial and economic; policy and sustainable development; and stakeholder engagement. Each specific isolated system will require a different pathway to optimising their smart energy transition around the concept that micro-scale solutions are useful for micro-scale problems. These isolated systems or islands should be enabled to benefit from innovation schemes, funds, policy, and regulatory mechanisms adapted to their needs. They may require specific implementation of solutions to address the wider set of barriers that can arise from complex interaction of all these factors in a milieu for which it was not designed. The focus should be on overcoming barriers related to the relatively small size, to network balancing issues and in addressing the unusual economies arising from the potential high extant costs and the unfavourable scale for new investment. In addition, the contextual situation of the isolated system informs the suitability of the various types of smart energy solutions such as electric vehicles or other generation sources such as combined heat-power (CHP), solar water heater and distributed generation within the system. This further emphasis the need for best practices for similar peripheral territories about what should be placed on each system's specific grid. To include optimising the investments within the system to deploy energy storage and shift to more active network management and demand response. This is a useful exercise to maintain reliability, enhance sustainability and potentially makes available more affordable electricity to island electricity consumers (Eurelectric, 2017).

The lessons learnt from transitioning islands and peripheral communities (as a laboratory with clean data) can help mainland areas better understand the technical, financial, operational challenges of the transition to smart energy solutions. The need to have insights into these systems aids the desire to understand the smart energy transition and for defining this general approach for undertaking such transition. As many of the case studies demonstrate, isolated areas provide a valuable testing ground for the real-world deployment of innovative storage, demand side technologies and other smart energy solution. The following section proposes a general methodology for isolated and peripheral community energy transition, which is developed and reported on within the ICE T2.1.2 deliverable report.

5. The ICE methodological approach

This section presents an overview of the proposed methodological approach to the design and implementation of smart energy island systems. It is informed by a desk review of the available literature on smart energy islands, current thinking in electricity system planning, and the challenges facing isolated systems (e.g. Ushant). The approach consists of a series of sequential steps and iterations between steps that aim to guide communities through the process of creating a smart energy island system. Unique to this approach is the emphasis of fostering local skills, businesses and industry in the delivery of the program with the aim of retaining these long-term benefits within the community.

5.1 Introduction to the ICE methodology

The proposed ICE methodology outlined here informs and aids the design of the ICE business model for the energy transition of isolated territories, developed in tasks T2.2 and T2.3 of the ICE project. The business model will promote employment, support labour mobility and enhance competitiveness of SMEs in the channel area and in other island or peripheral communities. The methodological approach proposed here is a generic and transferrable set of guidelines, designed to be applicable in a wide range of isolated or islanded contexts.

The approach builds on recent experiences of smart energy island transitions (see section 2) and known approaches to electricity system planning in general, and smart energy islands in particular. It covers issues such as general electricity demand, energy supply and capacity, energy efficiency potential, exploitable indigenous energy resources, social, environmental and legal constraints and the potential for smart technologies and practices.

The ICE methodology draws on the experiences and usage of methods such as integrated resource planning (IRP). IRP is a well-known and established method of electricity system planning that has been used by electricity utilities around the world since the 1980s as a transparent and participatory planning process for their electricity systems (Tellus Institute, 1999). IRP can make planning more open and can help identify pathways along which an electricity system may achieve future goals. IRP has been shown to be applicable in smart energy transitions on islands, where a whole-systems approach is particularly valuable (Campbell and Bunker, 2017).

The core of the IRP process is a series of steps, which are:

- (i) establish objectives;
- (ii) survey energy use patterns and develop demand forecasts;
- (iii) investigate electricity supply options;
- (iv) investigate demand-side management and energy efficiency measures;
- (v) prepare and evaluate supply plans and demand-side management plans;
- (vi) integrate supply and demand-side plans into candidate integrated resource plans;
- (vii) select the preferred plan;
- (viii) implementation of the plan, monitor, evaluate, and iterate (plan revision and modification).

Similar to the IRP process is an approach based on a readily available framework within which communities can organize energy transitions. This approach utilises a so-called 'action-oriented playbook' (AOP) to serve as a guide for the successful initiation, planning, and completion of a transition to an energy system that primarily relies on local resources (ETI, 2017). The AOP approach is project-oriented and includes a constructive dialogue together with resources and lessons learned from smart energy transition efforts undertaken by other communities. AOP entails seven phases:

(i) committing to an energy transition;
(ii) setting the vision;
(iii) assessing opportunity pathways;
(iv) project preparation;
(v) project execution and quality control;
(vi) operations and maintenance;
(vii) process improvement

The phases of AOP represent practical steps towards the community's goals. The actions are grounded in empirical observation of many island communities in pursuit of a smart energy system.

IRP and AOP are similar in some ways while distinct in others. Both are action-focussed, with local people and organisations the primary agents for change, unlike the concept of national energy roadmaps for islands which tends to focus on data acquisition and analysis (IRENA, 2017). However, IRP is a largely top-down, technocratic endeavour, in which change is expected to be initiated and shaped by an energy provider (usually a utility) to meet its interpretation of its users' needs, albeit with substantial stakeholder input. AOP, meanwhile, is a 'bottom-up' approach, anticipating that communities and their representatives work with utility managers as peers to affect change. The technical rigour of IRP and the consensual community-driven quality of AOP, rather than conflicting, present complementary lessons on the inception and guidance of system change. The ICE methodological approach, presented below, combines the planning aspects of IRP with the project focus of the AOP. It also expands the scope of both to incorporate the fostering of local businesses able to provide services in support of the transition, as shown in Figure 5.1, below.

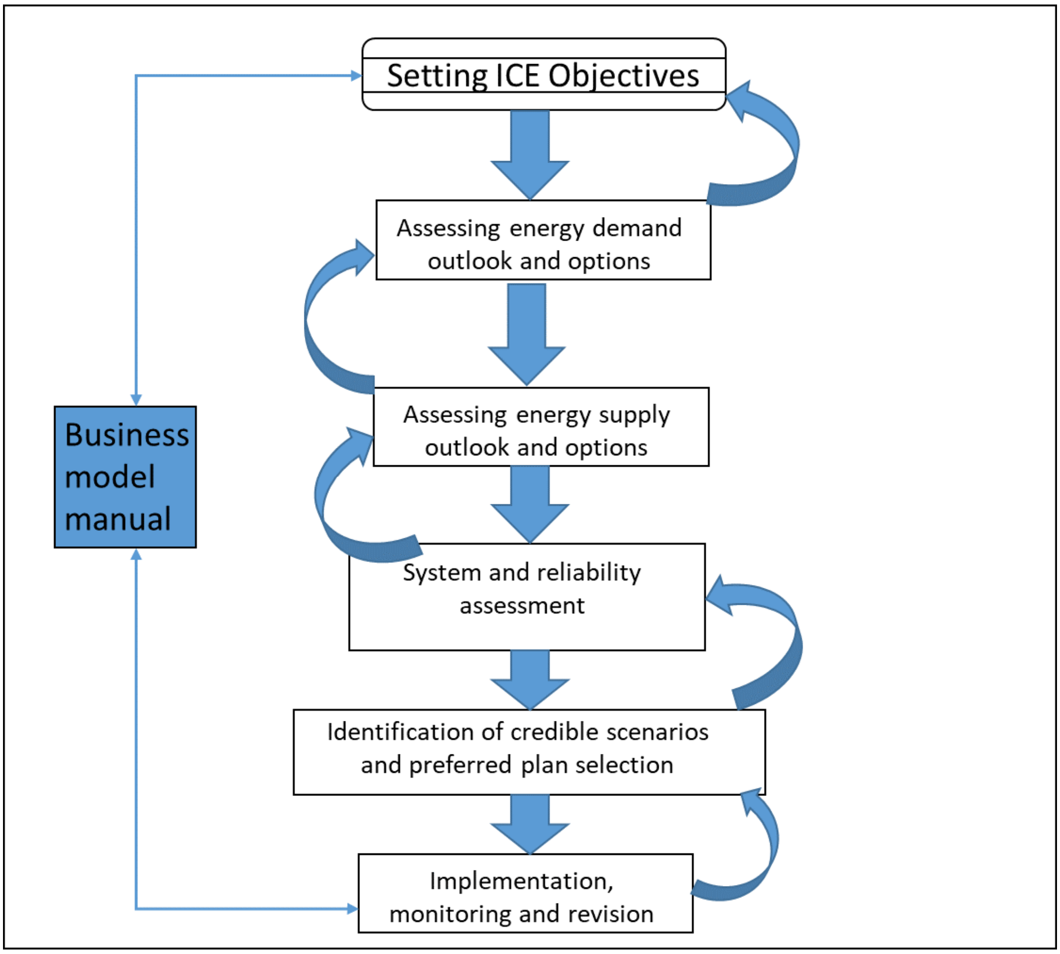

Figure 5.1: Schematic view of the ICE methodology approach

The proposed ICE methodological approach comprises seven interrelated steps. Six of these represent a hybrid, based on the most appropriate elements of the IRP and AOP approaches. The seventh element is a business model manual component, which will be adopted to the specificities of the isolated territories. The transferability and robustness of the ICE methodology for smart energy transition in isolated territories will be highlighted within the scope of the set of guidelines for the smart transition and the business model manual. This will ensure that there is consideration of energy security, target reliabilities, the technological and policy selection, and the options for comparative environmental impacts.

A set of guidelines for navigating the process are laid out in report T2.1.2.

Acknowledgments

The authors would like to thank their ICE consortium colleagues for their helpful input to this report.

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