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ELECTRICITY FOR EUROPE

EU ISLANDS:
TOWARDS A SUSTAINABLE ENERGY FUTURE

A EURELECTRIC report, June 2012

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EU islands: Towards a sustainable energy future

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Executive Summary

Some 2% of the European population lives on islands. The situation of these ten million Europeans in terms of energy supply is quite different from the rest of the EU population. As such, it deserves specific attention.

EURELECTRIC seeks to promote islands in EU energy policy and to initiate an EU Island Sustainable Energy Action Plan. This report closely analyses power generation in EU islands. It provides insights into the status quo of power supply and demand, looks into the regulatory framework, highlights best practice and presents solutions towards sustainable energy systems for islands.

Europe's islands are facing considerable challenges in meeting their energy needs in a sustainable, affordable and reliable way. Island energy systems, despite their diversity, share common characteristics and are subject to common challenges. Their sustainable energy future depends on an improved investment climate and policy framework. Five main challenges can be identified:

- **Market failure**: Due to their small size, islands lack economies of scale in financing and power production. They also face operational constraints originating from the isolated nature of their power systems. As a result, most islands do not enjoy many options for diversifying their energy supply and usually rely on oil-fired diesel engine generation for their power generation.

- **Inconsistent regulation**: The regulatory treatment of islands is not straightforward. Islands too often suffer from 'copy-paste' reasoning, whereby solutions from the mainland are applied to a different reality. Island markets are different and therefore require a different approach that is both reasonable and proportionate.

- **Security of supply:** Due to their isolation, islands have to take extra measures to ensure system stability and security of supply. Such measures demand more attention on islands than on the mainland with the growing penetration of variable renewable energy sources (wind and solar).

- **Emissions:** Islands' dependency on diesel engine generation will make it difficult and costly to comply with the forthcoming emission requirements of EU regulation.

- **Import dependency:** The reliance on oil imports for power generation renders islands very vulnerable to oil price volatility. The increasingly more stringent fuel quality requirements needed to meet environmental targets additionally impinge on the availability of such fuel.

Despite these challenges, power companies operating on islands are committed to change and forward-looking solutions. Acting through EURELECTRIC's Network of Experts for Island Energy Systems (NEIS), European island operators insist that policy changes are needed and present possible solutions for the move toward sustainability, as documented in this report's benchmarking section. The report makes the following recommendations to national and European policymakers to incentivise the transition towards a sustainable energy future:

1. Set up an EU Island Sustainable Energy Action Plan 2020
2. Improve security of supply through diversification of power generation technologies, as well as interconnection where possible
3. Use islands as a priority test-bed for innovative technologies such as storage, smart grids and RES. Foster RD&D on islands
4. Use exemptions appropriately and address the market failures that often occur as a result of limited size and isolation

Introduction

286 EU islands…

286 islands are located within EU territory. Their power systems are often isolated, with no interconnection to the EU mainland or to other islands. Their markets are limited, which makes investments difficult to justify. Their environmental situation is fragile and further weakened by non-sustainable tourism, especially on some Mediterranean islands. Their regulation is different from one island to the other, depending on the specific relationship between the relevant member state and the EU. In the best cases, a favourable interaction between the EU and the member state supports the island in facing its specific challenge.

There is a clear need for support and a step change. Depending on their size, economic structure, population and location, the power demand among islands varies. Although their location usually does not make diesel an obvious fuel for power generation, many nevertheless opt for this solution. While this is typical for isolated systems, it is neither sustainable, nor does it add to security of supply if used as the only fuel. In this, EU islands are not an exception but confirm the difficult situation faced by islands and small isolated communities worldwide. Awareness is fortunately rising, not only in Europe through EURELECTRIC, but also through the International Renewables Energy Agency IRENA for example, which has made the topic a priority on the global scale for 2012.

Despite the numerous challenges, power companies try to demonstrate alternatives and forward-looking solutions. But in order to do so efficiently and on the right scale, they need political support, reasonable and proportionate regulation and should be able to rely on a favourable investment climate.

This report examines power generation in EU islands. It provides insights into the status quo of power supply and demand, looks into the regulatory framework, highlights best practice and presents solutions towards sustainable energy systems for islands. The report is based on the expertise, experience and contributions of EURELECTRIC's Network of Island System Managers (NEIS).

The EU's Islands

According to EUROSTAT, an island is defined as an area of at least 1 km^2, located at a distance of at least one kilometre from the continent, that has a permanent resident population of at least 50 people, has no permanent link with the continent and does not host an EU capital. On the basis of this definition the European Commission's DG REGIO has identified 286 EU islands.

- Together, they are home to almost 10 million people occupying an area of 100,000 km^2.
- Their population varies from 50 people to five million in Sicily. The population of the latter exceeds that of EU member states like Luxembourg and equals that of Finland.
- EU islands are located in three major geographical areas: the Atlantic, the North and – accounting for 85% of the population – the Mediterranean.
- The 286 islands belong to eleven EU countries, with five member states accounting for over 75% of the islands.

With few exceptions islands' economic and social situation is less favourable than that of the country to which they belong. Their GDP per capita is thus usually lower. According to Bradley Dunbar[1] the average living standard is 72% of the EU average, with considerable differences among the group. Political autonomy also varies widely, with places such as the Åland islands being very autonomous while others having no administrative powers of their own.

The EU's islands are diverse: a few islands are very densely populated, while a very large number of small islands are sparsely populated. This evidently leads to varying market and investment conditions: the smaller the population, the smaller the market, and thus the greater the challenge of establishing a sustainable energy system.

It is worth mentioning that the EU definition for islands is not always straightforward. While islands within the territory of EU member states are included in the definition, island member states such as Malta and Cyprus are not. Nevertheless, they are also very much affected by the challenges islands face in terms of power systems.

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[1] Quoted from Planistat Europe, Bradley Dunbar Associates Ltd., Analysis of the Island regions and the outermost regions of the EU. Final report March 2003, consulted web 28.3.2012.

…facing significant challenges

Dependence on oil

Although many islands have abundant natural resources, most of them depend on external energy sources, mainly oil. Oil products account not only for the lion's share in transport, but also in power generation. The reason is simple: bulk gas shipping or gas/power interconnection with the nearest mainland are more expensive than oil imports, and the power system is too small to justify other investments at market conditions.

Missing interconnections

While islands close to the European mainland – like the British Channel Islands – are often already interconnected, remoter places cannot afford it. Larger Mediterranean islands are increasingly interested in interconnection with the mainland. Here the development of high voltage AC or DC subsea power cables falls within the scope of network development planners. Prominent projects include the planned EuroAsia power link connecting Israel to Cyprus and its extension to Crete and then the Greek mainland, and the interconnector from Malta to Sicily, which is under construction.[2] The EuroAsia power link however faces significant costs and would be nearly 1,000 km long, for a cost of approximately €1.5bn. High costs will restrict the number of islands going for interconnections to include only larger ones above a certain threshold and those relatively close to the mainland.

Islands as an opportunity for demonstrating energy solutions

But islands are not only an issue for concern – they also represent a unique opportunity. Thanks to their isolated and small integrated power systems they have the potential to become places of demonstration, as a test-bed for energy solutions. They represent microcosms of the larger European energy system in which new projects such as smart grids or electric transport can be tested quickly and effectively. Their smaller public authorities also mean that regulatory and planning decisions can be taken faster, speeding up decision-making and project implementation. Islands can therefore play an important demonstration role in the transition towards a carbon-neutral and sustainable energy system.

Report Outline

Despite making the case for islands at large, this report cannot take the entire range of the EU's 286 islands into account. It is therefore based on selected examples from within the EU territory, with some additional examples from islands located outside of the EU but affiliated to EU member states, where useful for demonstration and best practice.

- Chapter I presents the status quo of a number of selected European islands with respect to social, environmental and energy key performance indicators. These data have been gathered through a questionnaire circulated by EURELECTRIC among its member associations on island systems.

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[2] The example of the Malta - Sicily interconnector will be addressed in more detail later in the report.

- Chapter II outlines the main challenges faced by power generators on European islands.

- Showcasing different projects and best practices, Chapter III highlights solutions for island systems that deliver increased security of supply via a diversified fuel mix, but also through interconnection, more sustainability via reduced emissions both in transport and power generation, demand side measures and smart grids. Although many islands face similar challenges, tailor-made solutions are needed that take into account the specificities and uniqueness of each island in terms of location, size and legacy.

I. The Current Energy Situation on EU Islands

Small island power systems differ significantly from larger European ones in a number of key issues, which determine their current situation and their options for developing sustainable solutions. Firstly, most island power companies are vertically integrated. Furthermore, island electricity systems are characterised by a significantly higher generation margin. As their systems are not interconnected to neighbouring networks to import electricity in case of demand surges and generator faults, operators have to ensure security of the system at any given moment by creating high generation margins.

Another size-related challenge for small system operators is the lack of economies of scale. This often makes the usual way of unbundling and privatisation to open the energy market unfeasible, as the threshold for potential customers necessary to stabilise the market is often not given. Just as for larger energy systems, islands will need a stable and incentivising regulatory framework to tackle the challenges inherent to their systems.

Methodology

For the purpose of this report, a questionnaire was sent to the EURELECTRIC Network of Experts for Island Systems. It addressed the current state of isolated systems, their performance and the challenges they face.

Analysis of questionnaire responses

As a general rule island economies are more fragile than those of the mainland due to their small size, small market, and the related lack of strong industry. These factors, often coupled with an overdependence on tourism and the related vulnerability to the recession, have had a negative impact on almost all islands in recent years. One indicator for this is the high unemployment figures for many island societies, which are often reinforced by seasonal unemployment. In many cases, islands represent the regions with the highest unemployment figures in their EU member state. This is especially the case for islands depending on tourism, which are directly affected by economic downturn at home and abroad. The Spanish Canary Islands for instance had an unemployment rate of more than 32% in spring 2012, almost three times higher than the euro area's seasonally-adjusted unemployment rate of 10.9% and remarkably higher than the national rate.[3] Detailed unemployment figures for each island can be found in the annex.

Power demand

Like the mainland, islands experienced a decline in electricity demand throughout the recent economic slump, correlated with a decrease in GDP. However, according to our internal enquiry, **most European islands are expecting increases in electricity demand.** Islands expect an average increase of 24% from 2009 to 2020. This is a significantly larger increase than the 14% expected for the EU-27.[4] Figure 1 shows the total expected increase in power demand – an important development to keep in mind when analysing the challenges for islands in the next chapter.

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[3] Source: Eurostat, numbers for March/April 2012. Unemployment rate for Spain: 24.1% (March 2012)

[4] Source: EURELECTRIC Power Statistics 2011

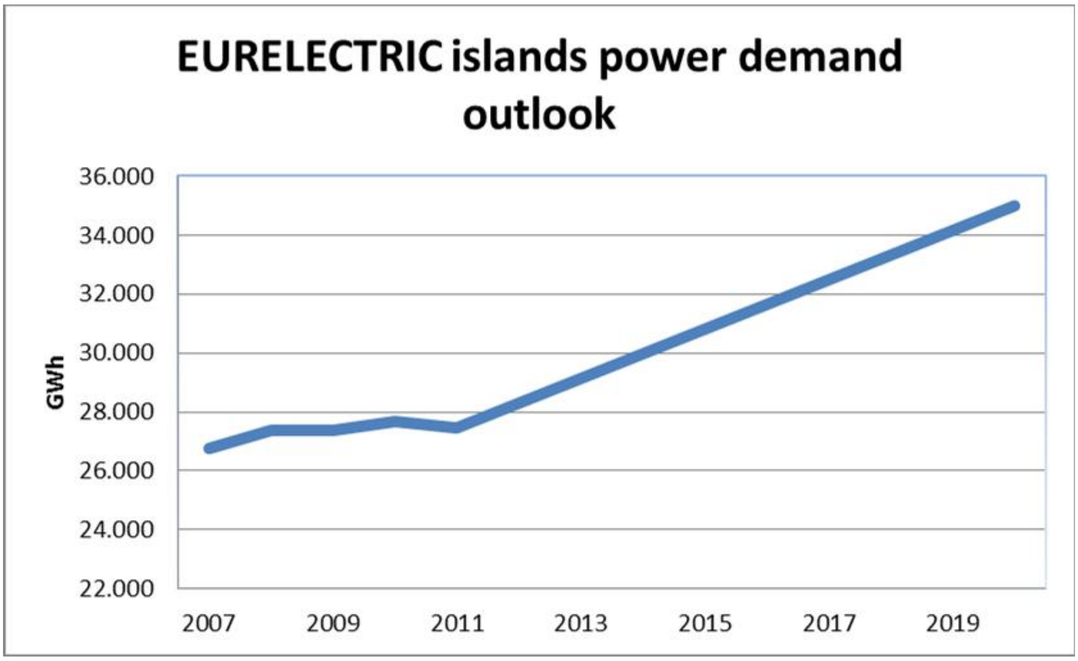

Figure 1: Island power demand outlook 2020 (Input dates 2007-2011, 2020)

Installed power generation technologies

The current electricity mix of most small islands is dominated by diesel or heavy fuel oil. The main reasons behind this choice are threefold: the relative ease with which fuel can be purchased and supplied (compared to e.g. supplying gas through a pipeline or by tanker as either liquefied natural gas (LNG) or compressed natural gas (CNG)), the flexibility of the installed engines in meeting daily and seasonal variations in energy demand, and the lack of storage. In order to maintain an appropriate security of supply, adequate levels of redundancy in case of a failure at a producing unit has led to the preference for several smaller units instead of one large generator. In addition, diesel engines' efficient operation across the volatile demand scenarios, along with their relatively low installation and maintenance costs, has made this technology the backbone of most island power generation systems.

However, significant economic and ecological drawbacks have led system managers to reconsider the status quo. High fuel costs, especially when fuel is bought in small quantities, combined with volatile fuel prices and increasing demands for better quality fuels to minimise environmental impacts all call into question the overreliance on diesel generation. The desire to remain flexible while reducing the dependency on expensive oil imports has created a strong economic incentive to change the system. Ecological incentives are equally relevant. CO_2, NOx and SOx emissions from diesel generation are high: 890g CO_2 equivalent per kWh calculated for the life cycle of a diesel-fired power plant.[5] Emission abatement technologies have been installed for NOx reductions at most conventional power plants on islands, which together with technological advancement have led to lower NOx emission levels in recent years. While more abatement technologies are technically available, and in fact have been installed at the new 144MW plant in Malta (described in more detail in Chapter III), technologies such as selective catalytic reduction and flue gas desulphurisation may not be suitable for most island systems due to variable power demand and frequent starting and stopping of generators.

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[5] See VGB Facts & Figures – Electricity Generation 2011/2012

The energy legislative framework on EU islands

Which policymakers should one approach to improve the regulatory framework for energy on islands – national governments or the EU? The answer is: both. Islands have different and often special relationships with the EU and with the countries they belong to. The difference stems from the accession treaty and a special protocol between the mainland and the European Union. This negotiated special relationship is based on previous agreement between the member state and the autonomous or semi-autonomous territory in question – in this case an island.

Figure 2: Punta Grande diesel power station, Canary Islands[6]

This bilateral approach between the EU and its member states has created a complex reality: some territories are formally part of the EU while others are not. All have particular arrangements or derogations under EU law. Moreover in some cases these initial arrangements have changed or are in the process of changing. Territories which are constitutionally linked to a member state and whose relationships with the EU are governed by primary Community law include: the so-called "ultraperipheral regions", the Overseas Countries and Territories (OCTs), the Åland Islands, the Faroe Islands, the Channel Islands, the Isle of Man, Gibraltar, Ceuta and Melilla. Of these, only the ultraperipheral regions, the Åland Islands, Gibraltar, Ceuta and Melilla are formally part of the EU. With the exception of Gibraltar, French Guiana, Ceuta and Melilla, all of these territories are islands.

The EU has always implicitly recognised the special nature and needs of islands, as shown by its diverse relationships with member state island territories and by the special derogations and arrangements negotiated with these territories. The EU has also recognised the particular situation of islands more explicitly in the Treaty of Amsterdam, which introduced several references to islands, in particular through Article 158 (Article 174 of the Lisbon Treaty).

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[6] All images in this report are provided by EURELECTRIC NEIS members and their partners

In developing a sustainable energy policy, islands could possibly benefit from several EU policies/instruments. The legal bases for support are Articles 170 (ex 154) of the Treaty of the European Union, (trans-European networks), Article 174 (economic and social cohesion), Article 349 (for particular islands) and Declaration 33 of the Lisbon Treaty.[7]

Support for islands' sustainable energy policy is notably put under the premises of broader regional policies. In addition, the European Investment Bank or the Marguerite Fund can provide support to islands for Greenfield infrastructure in transport, energy and renewables.[8] The European Commission's DG Energy also since 2010 supports the ISLE PACT[9] project, which aims to produce bankable sustainable energy projects on islands. EURELECTRIC NEIS and ISLE PACT are cooperating.

To conclude on our initial question whether to address national or European policymakers, it can be said that precisely because of the complex design of islands' governance, which is caught between national and European authorities, both are of equal importance.

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[7] **Article 174:** "In order to promote its overall harmonious development, the Union shall develop and pursue its actions leading to the strengthening of its economic, social and territorial cohesion. In particular, the Union shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions. Among the regions concerned, particular attention shall be paid to rural areas, areas affected by industrial transition, and regions which suffer from severe and permanent natural or demographic handicaps such as the northernmost regions with very low population density and island, cross-border and mountain regions."

[8] www.margueritefund.eu

[9] www.islepact.eu

II. Energy challenges for islands

Emissions

Emissions are clearly a challenge for islands, which generate the lion's share of their electricity with liquid fossil fuels.

Islands are heavily dependent on diesel generation. They have been largely exempted from the Large Combustion Plant Directive (LCPD), but this has kept them on an unsustainable path. Without support schemes and incentives, their transition to comply with the forthcoming requirements of the Industrial Emissions Directive (IED) will be very difficult and costly and introduce increased constraints on local generation.

Small isolated systems which obtained less than 5% of their energy through the European grid by the year 2010 benefit from a four-year derogation from the IED. They can continue to operate with the current emission limit values of the LCPD until 31 December 2019 (instead of 1 January 2016). This is justified with the huge economic consequences of applying the emission limit values (specified in Annex V) on island power sectors with a small or isolated network or insufficient interconnection. In the new IED certain emission limit values for SO_2, NOx, CO and dust have been lowered.

The EU's Industrial Emissions Directive (IED)

The IED revises and recasts seven directives (including the Large Combustion Plant Directive and the Integrated Pollution and Prevention Control Directive) into a single legal act. In line with the 'polluter pays' principle and the principle of pollution prevention, the directive sets out the framework to control the main industrial activities, giving priority to intervention at source, ensuring prudent management of natural resources, and taking into account, when necessary, the economic situation and specific characteristics of the place where the industrial activity occurs.

Prevention and control of pollution is ensured by only allowing the operation of installations holding a permit. The permit includes all the measures necessary to achieve a high level of environmental protection. The permit also includes emission limit values for polluting substances, or equivalent parameters or technical measures, appropriate requirements to protect the soil and groundwater, and monitoring requirements. Permit conditions are set on the basis of best available techniques (BAT). Emission limit values deviating from BAT levels are only possible where they would lead to disproportionately high costs compared to the environmental benefits. In any case however, the emission limit values set out in the directive should not be exceeded.

Within four years after publishing decisions on BAT conclusions, the permit conditions for installations must be reconsidered to take into account all new or updated BAT conclusions. It is important to highlight that combustion plants need sufficient time to install the necessary abatement measures to meet the emission limit values. In the case of installations which are considered to have a high environmental risk, the period between two site visits must not exceed one year. In the case of installations posing the lowest risks the period must not exceed three years.

While the IED does not exclude diesel engines, it does not specify any emission limit values for this type of generation. Emission limit values for diesel engines are expected to be established following the review of the best available techniques reference document (BREF).

Islands' limited generation capacity and isolated system requires them to upgrade plant emission standards by modifying and upgrading parts of the installation on a rotating basis. This rotation is a lengthy process but essential to guarantee continuity of service. Undue acceleration of this process raises the distinct possibility of power outages, with the consequent socio-economic disruption.

To comply with the IED, small isolated energy system operators could consider a number of options and decide based on a detailed cost-benefit analysis:

Option 1: Upgrading the existing generating plant to meet the emission limit values

Upgrading the existing generating plant (including the procurement of low sulphur fuel) in order to meet the IED emission limit values (ELVs). The attractiveness of this option would depend on the plant's remaining economic lifetime.

Option 2: Placing the plant as reserve plant

Placing the plant as reserve plant (i.e. operating no more than 1,500 hours per year on a rolling five-year average) and upgrading the plant to meet the associated less stringent ELVs.

Option 3: Opting for the limited life-time derogation

Opting for the limited life-time derogation of 18,000hrs starting from 1 January 2020 and ending not later than 31 December 2023, as specified in Article 33.

Option 4: Retaining some of the existing plant for emergency use

Making use of the possibility to retain some of the existing plant for emergency use, i.e. operating less than 500 hours per year. In this case they would not be covered by the IED emission limits.

In parallel to the IED, the UNECE (United Nations Economic Commission for Europe) **Gothenburg Protocol** already specifies emission limit values for NOx from diesel engines. However it does not define any emission limits for SOx and dust. The protocol has recently been amended to include updated national emission reduction commitments for main air pollutants to be achieved in 2020 and beyond.[10] Nonetheless, the previously specified emission limit values (ELV) have hindered the protocol's ratification by several countries who consider them to go beyond what can be achieved through the use of 'Best Available Technology' (BAT).[11]

It is important to ensure the emission levels in the proposed revision of the Gothenburg Protocol and subsequently the development of the BREF are reasonably feasible to implement and not disproportionately expensive. Small island electricity generators depend on the operational flexibility and efficiency of diesel engines to meet varying load demands. However the operation of emission abatement technologies is more problematic; especially with regard to damaged or poisoned catalysts and reagent supply issues for selective catalytic reduction (SCR). A diesel engine equipped with a SCR but with frequent load variation would not achieve the required emission limits. The safe disposal of poisoned catalysts and reagents is also extremely difficult for smaller islands.

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[10] At time of printing, the updated information relating to stationary diesel engines had not been published. For more information see Eurelectric's Recommendations for the revision of the Gothenburg protocol (2011)

[11] http://www.euromot.org/download/c1678d6b-c77f-49d9-bd52-d190479342e8/UNECE%20CLRTAP%202005%2005.pdf

Options foreseen in the review of the Gothenburg Protocol

The EGTEI (Expert Group on Techno-Economic Issues) have prepared technical annexes as suggested text to the revised Gothenburg Protocol. These annexes specify emission limit values for SO_x, NO_x and dust for various technologies. In the case of diesel engines only NO_x emission limits have been proposed. The suggested draft proposes several options (ELV1, ELV2 and ELV3):

ELV 1 - A demanding, but technically feasible option that only focuses on the reduction of one pollutant, NO_x. The plant will need to meet the lowest achievable emission rate or highest level of NO_x reduction. ELV 1 places high demands on the existing infrastructure and does not take into account the cost of implementing the BAT. It requires high-quality fuels, the use of an SCR with high efficiency and is designed for use in areas with poor air quality.

ELV 2 - Also technically demanding but pays attention to the costs of measures needed to achieve reductions. It is applied in polluted industrialised and urban areas with a good existing infrastructure. This would also require the use of an SCR with moderate efficiency.

ELV 3 (upper level) - The preferred option for areas with poor or restricted infrastructures such as countries in economic transition, islands and isolated regions. It is designed to be applied in areas with good air quality. Represents good practices based on the legislation of a number of parties, more details of which can be found in a Euromot report published in 2009.[12]

Regulation & market design

Market design is at the heart of the transition to the low-carbon energy system. Each market has its own unique characteristics – there is no universal model which is suitable for all circumstances. Such market models must factor in important physical and technical elements such as market size and network density. Yet the model applied to large markets may not fit isolated or small systems, justifying derogations on a case by case basis. The EU's 3rd Electricity Directive[13] has already recognised this: it provides derogations for market opening, third party access to the network and system operator unbundling to small and isolated systems/states, generally on the basis of (a) small system size, (b) isolation and (c) that achieving effective competition would be impossible or impractical.

Typically, islands are already burdened with additional costs stemming from their insularity. These negatively affect the cost of electricity by burdening the tariff with increased fuel and operating costs. Indeed, the challenge is very different from one part of the electricity system to the other. For example smart grid deployment could actually be easier in smaller systems than in bigger ones while the development of less mature power generation technologies like wind and photovoltaic might be more difficult. Island energy systems are generally characterised by very few independent power producers and are dominated by small generation units. They usually adopt a large generation

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[12] Euromot is the European association of internal combustion engine manufacturers. http://www.euromot.org/download/afa82be6-f3f0-44bd-974b-1e8f0d424f6f/UNECE%20Gothenburg%20euromot%20position%202010-02-17%20revised%20incl.%20executive%20summary.pdf

[13] 2009/72/EC

margin to support system reliability, have few economies of scale and experience a wide variation in load throughout the day and seasonally.

EURELECTRIC, which favours market-based mechanisms and is committed to a carbon-neutral power supply by 2050, acknowledges the limited markets or even market failures on islands and the need for complementary measures and remedies. We recommend a proportionate use of exemptions to address the obvious market failures (size, isolation). Islands are often subject to exemptions, which certainly represents the easiest way to turn a blind eye to the 'too small a market failure issue'. EURELECTRIC believes that exemptions should be granted as part of the move towards a sustainable energy system, not instead of this move. They should be approved on a case-by-case basis.

Security of supply and system stability

Electricity companies in Europe are striving to ensure a cost-efficient, secure and reliable delivery of environmentally friendly electricity to customers. This is also the case for islands, despite the more difficult operational constraints and the lack of interconnection. A faulty network cable can cause extensive outages in a small network which would not be seen on a larger interconnected grid system, as high fault currents trip adjacent circuits. Security of electricity supplies is a very important issue for island communities to protect their fragile economies and encourage investment in new and existing businesses. The relevance of this topic is also reflected in its recurrence during political elections in island communities.

In order to counteract systemic risks most islands **operate with generation margins of around 30-40% compared to 15-20% in mainland highly interconnected grid systems**. This high level of generation reserve causes extra costs but improves the reliability of electricity supplies.

For island energy operators, one of the main challenges is to achieve the switch to an environmentally sustainable energy production while ensuring a reliable, safe and economically viable production of electricity. Much like big, interconnected European power systems, islands are struggling to find ways to integrate variable renewables (RES) into their power systems and are increasingly looking into the feasibility of interconnectors or power storage systems to make the transition happen. RES, a set of at least ten technologies, have different technology-specific challenges. While they will constitute a key element of islands' energy transition, the variability of some RES technologies – above all wind and solar power – lead to new system stability threats and the need for balancing. Islands experience even more challenges in their move towards a higher integration of RES than the European continent since they cannot depend on the 'smoothing out' effect of a large balancing area.

Snapshot: Renewables in the EU

The European electricity sector is and will remain a major investor in RES in the coming decade.

RES covers a variety of more than ten different technologies with different characteristics – some variable, others not – and all on different tracks to grid parity. The take-off of technologies such as wind and solar will transform Europe's energy system, networks and markets. It represents a key investment opportunity for the power sector but will also pose unique challenges to the energy system.

EU electricity markets and utilities are experiencing fundamental change as a result of the EU's policy goals, especially the targets for 20% greenhouse gas reduction and 20% renewable energy by 2020. Fostered by national government support programmes and by EU legislation, new RES technologies have increasingly been deployed since the early Nineties. In the same period, electricity generated from renewables has continued to grow, reaching about 597.6 TWh in 2009.[14]

Society places a high value on reliable and affordable supplies of electricity. It is important that the increase in RES production, particularly from variable and non-dispatchable sources, is achieved without adverse effects on security of supply and at reasonable cost. The power system as a whole must therefore adapt to these changing conditions.[15]

Renewables will represent a significantly increasing share of generation technologies in the electricity mix, more than doubling over the next ten years. The 2009 Renewables Directive sets a 20% target for RES in total energy consumption by 2020, rising from a 2005 level of around 8%. The target is calculated as a percentage of total final energy consumption, including all energy use – electricity, heating & cooling and transport. Depending on the scenario, the overall 20% target will require RES to deliver almost 35% in electricity.

The increasing capital, competence and market knowledge required to succeed in technologies generating electricity from renewables have also strengthened the role of the electricity industry, which has become the key industrial driver in this development. EURELECTRIC members have been investing significantly in such technology and integration over the last ten years: according to the EURELECTRIC *Power Statistics 2011* renewable energy is the largest area for investment in terms of capacity. In 2010 alone, EURELECTRIC members invested in an additional 10.2 GW of wind and 5.8 GW of photovoltaic.[16] The electricity industry represented by EURELECTRIC is not only investing in the most mature RES technologies, such as onshore wind. They are also the leading industrial investors in offshore wind projects, which are very capital-intensive and technically challenging. Today's major projects of offshore wind development include Greater Gabbard, London Array and Dogger Bank.

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[14] Source: EURELECTRIC Power Statistics 2010

[15] See EURELECTRIC's Renewables Action Plan, October 2011

[16] Source: EURELECTRIC Power Statistics 2010

There are seven points which suggest that the variability related to some RES technologies poses a more significant challenge to an isolated island system than to a larger grid:

Relative plant capacity: commercial scale RES installations will represent a considerably larger proportion of total installed capacity or customer demand on an island system. For example, the Thanet offshore wind farm in the UK (heralded at inception as the world's largest offshore wind project) at 300MW capacity represents just 0.3% of UK installed generating capacity and comprises 100 turbines. By contrast, a single 3MW wind turbine connected to a 100MW island power system already represents 3% of capacity.

Diversity considerations: weather diversity over a large area can help to balance variability, if interconnection capacity is sufficient. On islands this is not possible.

System capacity margins: the combination of variability, relative plant capacity and lack of geographical diversity means that an island power system will need sufficient back-up plant to cover variations in output from any of the variable renewable sources. Current capacity factors for variable RES range from ca. 19% for onshore wind inland (1,700h/a) to 24% for onshore wind at the coast (2,100h/a). Depending on location solar PV capacity factors range from ca. 11% (950h/a) in central Europe to 20% (1,750h/a) in southern countries like Spain.[17]

Conventional and back-up plants: back-up plant will need to be sufficiently responsive to meet variable demand cycles and will need to operate at a relatively low load factor with more RES in the mix. This presents technical challenges for the selection of back-up plant and also affects the purchase, operation and maintenance costs of suitable plant operating at low load factor only.

Storage: next to sufficient back-up capacity, centralised and decentralised storage solutions and potential interconnections are key enabling technologies for island systems aiming for high RES targets. This will be addressed in more detail in Chapter III.

Frequency and voltage regulation: variable RES sources may be easily absorbed into large-scale power systems, especially at modest penetration rates. However, integration issues will be more predominant in a small-scale system; therefore frequency will be of greater concern.

Emissions: operating conventional thermal plant at low load factor or frequent start/stop operating conditions will inevitably reduce the efficiency of that plant and increase the 'per MWh emissions'. While the net contribution from RES to emissions reduction will still be positive, it may not be immediately as great as expected.

Of course, this does not mean that RES has no part to play in an island system. To the contrary, island systems actually offer an excellent opportunity to examine all of these factors in a detailed and controlled manner. Such investigations may subsequently provide valuable guidance towards deeper penetration of RES in island systems and on the mainland. However, it should be recognised that the island utility might incur greater costs and technical difficulties.

The variability of wind and solar introduces extra costs within the supply network. The experience of island communities operating such sophisticated system stability and network management systems is of direct relevance to mainland communities who operate power zones with high levels of embedded generation. Island communities also need to invest in very quick protection and clearance of faults on the network, to prevent cascade tripping of large areas of the network. Such

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[17] Source: Siemens, 2012

devices require reasonable investment in order to achieve security of the network under fault conditions.

Oil imports and price volatility

Heavy fuel oil is the dominant source of oil used by island communities for diesel generation. Gas oil is often of secondary importance, to either assist with the start-up and closing down of diesel engine generators or for use in fast-start simple cycle gas turbines for emergency supplies.[18] The high volatility of the oil price has thus become a major cause of concern, causing operators to often implement protective measures such as oil and currency hedging. Due to a lack of space, islands often cannot store large quantities of fuel, denying them options to buy more selectively.

Island communities are dependent on the lengthy and often costly supply chain associated with oil import on a small scale. The lack of good port facilities in many of the smaller islands is equally challenging, requiring the use of small bespoke ships which are expensive to use and service.

The choice to use heavy fuel oil (HFO) instead of gas oil has been driven by its lower cost. However, improved cracking of crude oil into lighter more valuable products has decreased the availability of HFO, leading to higher HFO prices. The HFO price has also increased because of EU requirements to considerably reduce its sulphur content. As a result, the cost of producing electricity in islands and isolated communities has increased. The EU requirement to use ultra-low sulphur HFO has made it more difficult to source such fuel for most islands, which have traditionally used the same source as the marine industry – which has yet to adopt this ultra-low sulphur specification for HFO. With availability of the desired resources remaining limited, island operators are increasingly forced to import fuel from more distant locations, a situation which undermines the ecological purpose of using cleaner fuel.

The problems of the supply chain also extend to the shipping, which now has to comply with stricter regulations to prevent pollution. These tighter regulations have seen many older vessels withdrawn from service, producing a higher demand on the remaining ships, thereby further increasing costs. All of these issues place more difficulties on managing the generation business in island communities, but they also encourage innovative solutions to producing energy from sources other than oil and improving the efficiency of any oil that is used.

In sum, island communities have to pay a premium price for heavy fuel oil (and gas oil) and are struggling to find suitable ultra-low sulphur sources from nearby refineries and suppliers.

Heavy fuel oil shortages

The price of heavy fuel oil is rising steadily, with huge volatility (see Figure 3). The increased pressure in fuel oil prices is explained by a combination of low supplies (as refineries are shifting output towards petrol and diesel) and increased demand for low-sulphur fuel oil for electricity generation in Japan. The price rise and volatility are expected to continue, thus exposing islands with a major share of diesel power generation to high fuel costs.

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[18] Note that in very small islands the more expensive gas oil is often the only fuel available for generation.

Figure 3: Fuel price volatility 2008- 2012

Refineries phasing out fuel oil production

The physical markets have seen a substantial drop in fuel oil supplies as refineries are cutting back on the fuel oil yield from each barrel of oil. Many refiners are upgrading existing refining facilities, focusing primarily on the ability to process the heavier bottom of the barrel crude (which yields the fuel oil component) by adding heavy oil conversion processes such as hydrocrackers, which use large quantities of hydrogen to produce more expensive refined products such as petrol, kerosene and gasoil components. As a consequence, global fuel oil yields have dropped sharply over the past decade, whereas the light product yields have increased. The Financial Times has reported that the percentage of each barrel of crude oil that is converted into fuel oil has dropped by around 15% in 2002 to 10% in 2011.[19] The upgrades within the refinery industry clearly raise the possibility of fuel oil supplies remaining at low levels, which will in turn lead to keeping prices well supported.

Following the March 2011 earthquake and tsunami, Japan’s use of oil-fired generation – both using fuel oil and direct-burning of crude oil – has increased sharply to compensate for the reduced nuclear output. Should the country decide to do away with nuclear power completely, fossil fuel consumption will inevitably rise sharply in the short and medium terms.

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[19] See Financial Times, 24 January 2012

Countering price exposure: Enemalta Price Hedging

Oil Hedges

Rather than adopting zero-cost collar structures, from 2010 onwards Enemalta has hedged its fuel exposure using a swap structure, locking in its price.

Description of a Swap Instrument

A fixed price swap allows Enemalta to lock-in a fixed purchasing price over a certain period. The fixed price of the swap protects Enemalta against the underlying price increases. On the other hand, Enemalta does not benefit from potential underlying price decreases.

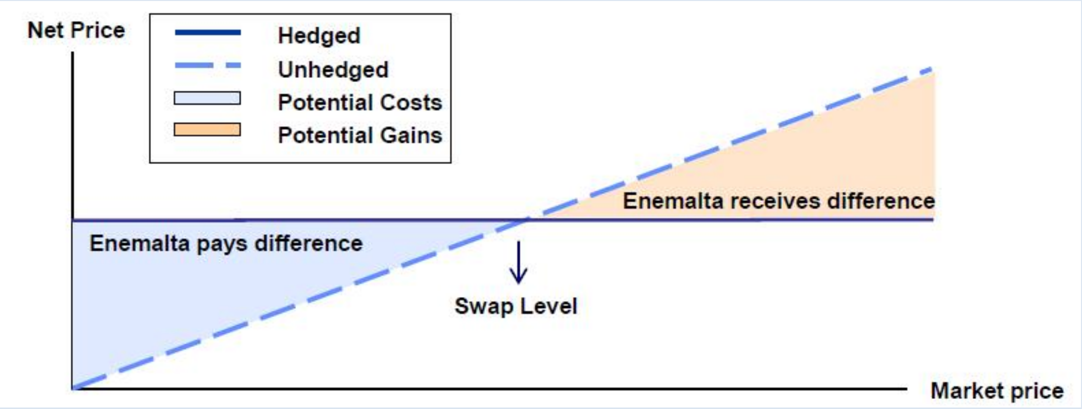

Figure 4: Swap Structure

Why Swaps?

This swap structure adopted for Brent hedges has provided an element of stability in devising Enemalta's tariff model. By locking-in prices through swaps, Enemalta also gains greater control over its variable fuel costs. As opposed to collars, Enemalta also achieves complete price protection from any increase in crude oil prices.

FOREX Hedges

Enemalta mitigates the risk related to its exposure on the dollar requirements by using flexible forward contracts: a deal to exchange euros for dollars at an agreed date in the future, at an exchange rate agreed today (forward rate).

Cost matters more on islands...

While islands face the same challenges as the mainland, albeit on a smaller scale, they usually do not have the option of energy imports and export. This places a significantly higher burden on the local island systems. Solutions are more expensive, while island economies are more fragile. A common concern among island utilities is the financial burden stemming from high and sometimes peaking prices of oil, the main fuel for power generation on most islands. Price speculations are often unreliable, which decreases island operators' financial flexibility in implementing more sustainable solutions.

RES financing obstacles for EU islands

For EU islands, finding financial support can become quite complicated. Their support schemes for energy installations are often aligned with the mainland system, without taking islands' cost-specifics into account. This situation has led island operators to seek additional support and an accumulation of grants from specific national financing schemes, which are often seen as "too state aid intensive" – and therefore forbidden by the European Commission.

A possible solution would be to take the real power price on islands as a reference to calculate the intensity of state aid, an aspect which should be given consideration during the revision of the Commission's state aid guidelines for environmental protection. Financial criteria (and risk/return balance) for innovative projects should therefore reflect the specific situation of islands and the higher weighted average cost of capital island projects usually imply.

III. Best practices and options ahead

European islands are at the crossroads of modernising their power generation infrastructure to meet the challenges and targets of the next decade and beyond. Meeting rising demand with more sustainable energy in the mix and better management of the system in an uncertain legislative and financial environment will be the crucial challenge for island system managers.

There are some common features to the energy transition that islands are experiencing, with all islands tapping into a basket of diversified energy solutions **(Section A).** Almost all islands plan to decrease power generation from diesel engines and/or fuel oil. One trend is the plan to shift from oil to locally produced or imported gas, which is expected to become viable due to low LNG prices. In this scenario, gas-to-power will also take on the role of backing up renewable energy sources as a flexible generation technology. A common alternative is the trend to modernise and decrease oil-to-power generation and use its flexibility to back up intermittent RES in combination with energy storage. This strategy also includes the installation of enhanced abatement technologies so that the fossil fuel generation meets national or European emissions targets. A third strategy is the increasing reliance on interconnectors, which offers a solution to security of supply and intermittency challenges, albeit with a high price tag. Many islands are also on their way to testing and implementing demand side management systems such as smart meters to increase efficiency and prepare for future implementation of smart grids. However, every island will find its own way, as illustrated by the examples of benchmark projects in **Section B**.

A. Key principles & trends

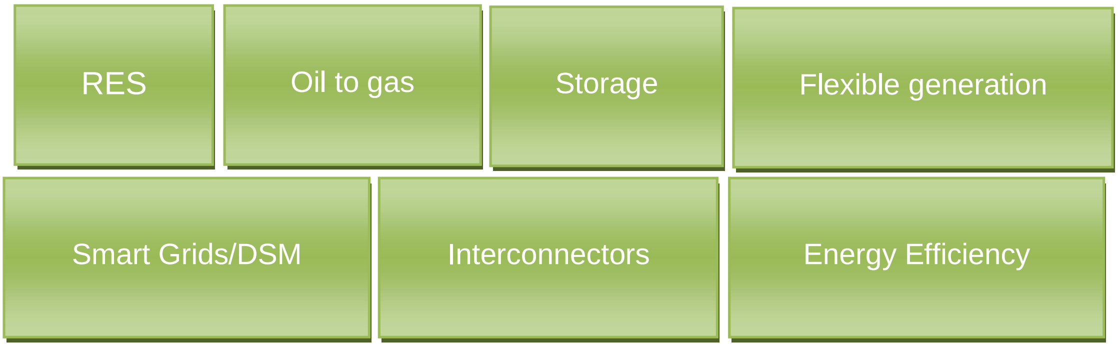

Figure 5: The Energy transition on islands will be achieved through a basket of solutions

Islands moving towards low-carbon generation led by RES

Our analysis of islands shows a clear tendency towards the installation of renewable energy sources over the last years. RES capacities on the vast majority of islands are growing, with **wind power being the preferred choice.** Onshore wind make up the lion's share of installed and planned RES capacity, followed by hydro and, depending on the region, geothermal or solar energy. Larger islands have set the scene for offshore wind farms. Overall, the total energy generated from renewable sources among questionnaire participants increased by 16% over the last five years.[20]

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[20] See Annex for tables with generation per technology

Although diesel generation is set to remain the predominant technology for most participating island utilities, its share in electricity generation is projected to fall significantly from currently about 76% to about 31% in 2020.[21] The strategies for replacing diesel differ, depending on size and location. Beyond RES, two solutions predominate: the switch to gas and interconnection, where feasible. Diesel is considered by many as an important back-up fuel for balancing variable renewables, which are still to be set up. While the overall role of oil is decreasing, several islands are in the process of planning or constructing new diesel-fuelled generation units to either increase overall generation capacity or to replace ageing plants with more fuel-efficient and less polluting capacities.

As a result of this trend towards low-carbon technologies (more RES capacities, increasing efficiency, use of abatement technologies) emission levels have been decreasing: from 2007 to 2011, CO_2 emissions fell by an average of 10%. Over the same period, NOx emissions decreased by an average of 13%, mainly due to the installation of NOx abatement installations at many power plants.

Interconnections – an alternative to local power generation?

Another noteworthy observation is the trend for larger islands or islands close to the mainland to install connections to the mainland. Such a connection not only increases security of supply, but it also allows the import of low-carbon electricity which can be used for example to back up local, intermittent renewable capacities.

Interconnection between the isolated island system and the mainland through high voltage AC or DC subsea cables entails manifold benefits for both sides: interconnections increase security of supply; the power mix can be decarbonised more easily and more cost-efficiently; flexibility for variable renewable sources is available without the need to set up new power plants; it provides an alternative to missing or costly storage; and islands can take advantage from trading in both directions. Depending on the price levels on both sides, islands might find import more attractive than domestic generation. Or, as witnessed in winter 2011, island utilities might export electricity to benefit from high electricity prices on the mainland.

The numerous advantages of interconnectors to larger mainland systems have led a number of islands to either increase their connection capacities, such as the British Channel Islands, or to decide to build first connectors, even across larger distances. Prominent examples for this development are Malta and Cyprus. The Maltese decided to construct a 120km (95 km of which are subsea) 200MW HVAC submarine interconnector to Sicily, which is to be operational by end 2013 at an estimated cost of around €200 million. In early 2012, the Electricity Authority of Cyprus signed a memorandum of cooperation with a local utility to enable the construction of a subsea power connection with Israel and Greece via the island of Crete. After a feasibility study, the link could be finished in 2016, connecting the island to both European and Israeli mainland. The nearly 1,000km long connection is estimated to cost €1.5 billion. The investment costs for interconnector projects represent a major obstacle for most islands to realistically consider their implementation. Depending on the geography of the individual landscape, even interconnectors between islands in a group such as the Azores may be too costly to be considered feasible (e.g. due to extreme depths between islands).

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[21] This sharp reduction is in particular due to plans from Cyprus and the Canary Islands to switch fuel for power generation almost completely from diesel to gas/LNG by 2020. See the Annex for further details

Oil to gas switching

Several larger islands or island groups, such as Cyprus or the Canary Islands are planning to almost completely switch the fuel used for their power production from oil to gas/LNG by 2020. Liquefied gas in particular has been investigated as an alternative fuel for the future. LNG is natural gas that has been cooled down until it becomes liquid. Natural gas liquefies at about -163°C, where it takes up only about 1/600 of the space of the gas itself. It is therefore a space-saving method of transporting natural gas. When allowed to warm, the gas evaporates and returns to its normal state of gaseous fuel, whereupon it can be used to generate power. It consists mainly of methane (CH_4) which potentially is a very attractive fuel for power generation. Methane has the lowest carbon ratio of all fossil fuels – only 75% carbon by weight. By comparison, heavy fuel oil is about 87% carbon.

Natural gas can be used as a fuel for a range of plants, including both gas turbines (simple and combined cycle) or reciprocating combustion engines. Both types of plant are already widely used for island power generation. The reciprocating engine in particular represents an interesting opportunity for gas generation for a range of reasons:

- Similar engines have been widely used by island power utilities; the technology is largely well-known and understood;
- Reciprocating engines offer the flexibility, economy and efficiency that have made them the mainstay of island systems;
- They are highly efficient – even in ‘simple cycle’ configuration they can operate at thermal efficiencies rivalling CCGT plant, especially in load following or intermittent operating cycles.

Using natural gas as a fuel for power generation offers considerable emissions benefits over ‘traditional’ liquid fuels such as diesel or heavy fuel oil. Typically CO_2 emissions can be reduced by up to 25%, NOx by up to 85%, whilst SOx and particulate emissions are virtually zero for natural gas.22 Natural gas represents a straightforward option to meet increasingly stringent emissions objectives, without the need for exhaust after-treatment such as scrubbers or selective catalytic reduction technologies. Figure 6 shows the emissions of different fuels used in the shipping industry for cargo ships propelled by a reciprocating engine. These differences are indicative of the emissions benefits offered by LNG over distillate or low sulphur residual fuels.[23]

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[22] Source for engine emissions performance on natural gas: Wärtsilä Corporation

[23] Greener Shipping in the Baltic Sea, Det Norske Veritas, 2010

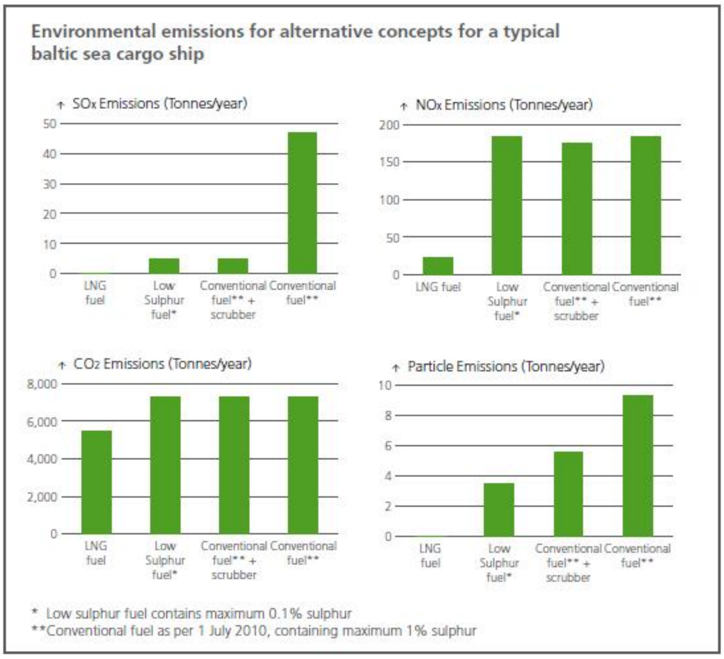

Figure 6: Emissions by fuel type

Natural gas is a 'tried and tested' fuel for both gas turbine and reciprocating engines. In some cases, existing plant could be converted to gas or dual-fuel operation. The main technical problems with use of gas would be the requirement for new LNG storage tanks, unfamiliarity with the handling and usage of LNG, and issues associated with the very cold storage temperatures. At present there are no harmonised international standards for the operation of LNG bunkering or storage facilities. However these could be replaced by more extensive case-by-case risk analyses in the meantime.

LNG is widely available, with worldwide production increasing.[24] LNG prices on international market long-term contracts are presently about half the price of crude oil when expressed in terms of price per million BTU.[25] For island utilities, this price advantage is currently eroded due to lower consumption, re-liquefaction and transportation issues. However LNG retains the potential to provide an economic fuel for island utilities.

While LNG clearly represents an attractive fuel for island utilities, its major drawback is the lack of smaller scale liquefaction and transportation infrastructure that can deliver the required quantities to smaller island generators. A 100MW LNG-fuelled reciprocating engine plant would typically need about 40,000m^3 of LNG storage for a six week strategic stock.[26] The majority of existing LNG transportation comprises vessels of about 145,000m^3 which would be too large to provide a routine service to a smaller island utility operating a plant of this size. Until smaller LNG carriers become more widespread, the use of LNG among island utilities is likely to remain limited. Nonetheless, there does seem to be increasing interest is this area. If LNG becomes more widespread as a fuel for the shipping industry, the emergence of a network of LNG terminals would be required to support it. This in turn may provide the basis of an LNG infrastructure to support island generators. At present however, the very high costs of LNG re-liquefaction facilities as well as the difficulties in acquiring LNG in small quantities often bar the way for LNG as a real alternative to diesel generation, especially for smaller islands.

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[24] BP Statistical review of World Energy 2011, bp.com/statisticalreview

[25] Greener Shipping in the Baltic Sea, Det Norske Veritas, 2010

[26] Source: Wärtsilä Corporation

Smart grids, demand side participation and energy efficiency

Smart grids and demand side participation

Smoothly integrating renewable energy sources (RES) into the electricity system will only be possible if the system becomes much more flexible. This can be achieved by developing intelligent networks, so-called smart grids. Smart grids will also foster what we term demand-side-participation, which will in turn help make the electricity system fit for the future. Thanks to a smart infrastructure, customers will be increasingly able to manage and adjust their electricity consumption in response to real-time information and changing price signals.

Each electricity network (including generation) is designed, built and operated to meet the maximum demand that the customers acting together request from the network. The system must be capable of meeting and exceeding this peak demand to allow for future growth. At the same time, demand varies considerably during the day and seasonally. This variability leads to poor utilisation of the network: some networks operate at less than 30% of nominal capacity for most of the year. Nevertheless, the one day that demand peaks, the network must be able to service that demand or the network will fail, subjecting electricity customers to large-scale interruptions.

Any technique to reduce and shift demand to other times in the day is beneficial to asset utilisation and capital investment, which in turn can reduce tariffs. Managing the load curve and reducing the growth of system demand can therefore be useful for customers as well as utilities. In small island communities with a good understanding of how individual customers contribute to overall demand, it is easier to manage this demand than to achieve large interconnected networks. The use of 'time of day' tariffs with high prices during the network peak allows educated customers to manage the cost of their energy by reducing their peak energy consumption.

The principle of 'time of day tariffs' can be extended to dedicated circuits such as heating and cooling circuits. Such circuits can be managed by central control systems that turn off the circuits at system peak.[27] Intelligent appliances such as fridges and freezers can also be turned off for brief periods (or in the near future reduce or increase the power demand by directly managing the controls of the appliance) without affecting operation. If large electrical loads and the charging of electric vehicles are introduced into this type of intelligent system, a network operator can continually switch loads on and off to produce a flat load curve. This effectively removes system peak, significantly increases asset utilisation and reduces capital expenditure.

This smart network monitoring and switching/controlling loads on a continuous basis is the future vision of many electricity network designers. Demand side response is one of the answers in balancing supply and demand. It is of vital importance for the electricity networks of the future and can play an important role in optimising the energy use of all customers.

Energy efficiency options

The close interaction between island communities and government offers a society which can easily adapt and adopt new technologies. Considerable opportunities exist in such communities to embrace technology and initiatives to improve energy efficiency and manage system demand growth. This may not necessarily mean a reduction in energy sales per capita, but customers switch

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[27] Sometimes also referred to as 'off-peak' tariffs

from lower efficiency energy systems to alternatives generated with higher efficiency. Additionally, customers are encouraged to use electricity at times which avoid system peak.

Since system peak drives capital investment in generation and the electricity supply network, energy sales which avoid system peak can reduce capital investment. At the same time it also improves asset utilisation and generation efficiency, since generators do not have to 'cycle' as hard to meet a volatile load curve. This often lowers emissions from power generation.

Several options can be used to improve energy efficiency and assist in system demand:

- **Electrical appliances**

The improved design of electrical appliances can achieve significant savings in energy. Customer awareness campaigns and lobbying of retail business can be effective in island communities to ensure only efficient electrical appliances are available for sale. The strict application of energy efficiency information on products can also assist customers in making the right choice.

- **Heat pumps**

Heat pump technology for heating and cooling now offers up to 5 to1 energy efficiency, giving rise to considerable savings compared to older cooling devices and traditional heating systems, while giving customers better value for money.

- **Building regulations**

Island communities should embrace new building materials which make properties more energy efficient and ensure reduced energy needs per dwelling. Government agencies and the local federation of building contractors should be consulted and encouraged to take such initiatives at every opportunity. Many simple low-cost initiatives in this area could produce quick and easy results while embracing traditional designs to provide shade in sunnier communities and retain heat in northern communities.

- **Solar thermal panels**

Even in the northernmost community solar thermal panels can provide cheap and effective water heating for many years. When coupled to a building energy management system, even more savings can be achieved.

Interconnectors grow - slowly

The increasing difficulties and risk of shipping oil and the volatility in oil prices have led oil-dependent island communities to investigate the possibility of submarine cable interconnection with nearby mainland countries or other islands. Such interconnections are often the only alternative to the high cost of renewable technology supported by energy storage or conventional diesel generation. LNG or compressed natural gas technology is not economically viable for small island communities.

Benefits of submarine cable interconnection

Submarine cable interconnection allows island communities to access a competitive market for electricity where scale and market forces have acted to reduce costs. Cable interconnection also improves system stability and increases reliability. Interconnection between islands can pool generation assets and effectively provide a larger community within which to spread the fixed costs associated with generation and supply.

The cost of cable interconnections can also be cheaper compared to that of conventional diesel generation. The capital cost per MW of a submarine cable can be less than the capital cost per MW of local power generation, although this obviously depends on the type of cable technology and the required circuit length. Typically AC transmission becomes more difficult for a circuit length in excess of 50 kilometres from substation to substation. Beyond 100 kilometres, DC interconnection clearly becomes the preferred technology. But with improvements and innovation in submarine cable technology, HVAC circuit lengths in excess of 100km can become economically viable, as exemplified by the interconnector between Malta and Sicily. These HVAC interconnectors have several advantages over HVDC cables, with perhaps the most important being the synchronous connection and the overload capability which approaches 80% for one hour, thereby acting as a very economical source of shared spinning reserve.

Maintenance costs for submarine cable systems are very small compared to those of generation. However repair costs can be significant and insurance against such repairs is expensive.

Figure 7: Construction of power distribution networks, Jersey

The emission benefits from using cables which displace traditional diesel or oil-fired generation can be significant. Any energy transported across an international boundary, under the Kyoto Protocol, is rated at zero carbon emission. Even if this is not the case or applied to such energy exchanges, access to larger electricity markets does give the opportunity to buy low-carbon electricity on that market at a significantly smaller premium to that of providing such facilities within the island community.

Disadvantages of interconnection

The environmental impact of cable interconnections is clearly considerably smaller than the impact of traditional diesel generation, but it is nevertheless important to complete a thorough environmental impact assessment concentrating on marine life, sea bed effects and fishing interaction. It is important to engage with interested parties early on in the project to ensure their concerns and objections are properly dealt with and that actions are taken to minimise the effect of such installations.

In order to provide reliability, at least two cables are required to give N-1 security – but the capital cost of a second cable is often prohibitive. It is therefore common to install one cable only, the loss of which is supported by traditional generation stored in an operational ‘light condition’. Such light storage of the diesel generation incurs additional maintenance charges, but these are small compared to the investment required for an additional submarine cable.

In reviewing the advantages and disadvantages (provided the cost of a cable is less than that of traditional diesel generation) across an investment period of 20 years or more, cable interconnections clearly offer islands a method of participating in a larger energy market, which may provide access to cheaper electricity and improve reliability. However, some capital may be required to retain standby generation facilities in order to meet the security standard against a single cable circuit. Expenses would also be incurred in monitoring the cable circuit against cable damage from trawlers or dragging anchors. Such issues would depend on the sea bed and the sea depth. In any case care should be taken to ensure that the cable is properly installed and buried where possible.

A typical 100 MW AC installation across a distance of 50km would cost about €60 million. A 200MW AC installation with a circuit length of some 100km would be some €160 million. A DC alternative would cost slightly more and require the installation of two AC/DC conversion stations. The Malta-Sicily connector (see Section B) gives some further indication of expected costs, although generalisations are difficult.

Storage

Storage as a key enabling technology for small & isolated systems

Finding an effective and economical way of storing power is one of the current major challenges for the European power sector. A central concern for island operators is the fact that the power output of many renewable energy sources is not as reliable and as easy to adjust to changing demand cycles as the output from traditional power sources. This disadvantage could be overcome by storing excess power produced when electricity generation is larger than the demand. Efficient storage could also solve a number of other problems related to efficiency, balancing and security of supply. Especially for isolated systems like islands, storage therefore represents a key enabling technology that addresses many of the challenges outlines in Chapter II.

Specifically, the right energy storage can fulfil several functions in an isolated power system:

- Peak shaving (hours to weeks);
- Stabilising intermittent production (minutes to hours);
- Voltage and reactive energy control (minutes to hours);
- Frequency control (seconds);
- Quality of electricity (seconds);
- Continuity of service (seconds to hours).

Figure 8: Construction of the upper reservoir of the hydro storage plant, El Hierro (Canary Islands)

With the increasing penetration of RES in the island generation mix electricity storage will play two important roles. First, it will be a source of efficiency, as it allows RES-electricity to be captured and stored for later use, thereby using resources which would otherwise be lost. Second, it can help provide the needed flexibility to counter intermittency issues and ensure system stability. The installation of storage capacity will therefore allow operators to make full use of the RES potential in their territory.

Research, development and deployment efforts are currently testing and enhancing a number of different storage technologies. In this case, islands' small size works in their favour, as storage capacities which might be too small to play a significant part in large power systems may take a more central role in an island system. Depending on the technology installed, some power storage options can help to rapidly respond to short peak power requirements while others offer the solution to balancing annual fluctuations.

Next to power storage, operators are increasingly looking into storage for heating and cooling. For many islands in warm climates, air conditioning systems are a major factor in power supply, especially during peak demand. A common method to minimise the impact of cooling devices on peak power demand is ice storage, in which excess electricity during off-peak times is used to generate large amounts of ice in special cooling facilities. This ice can then be used to chill the coolant liquids of the air-conditioning system at peak times without the need for additional energy.

Storage options

Storage comes in different types and sizes. Pumped hydro and compressed air storage are dedicated for large energy amounts, while batteries are geared towards smaller projects of less than 100MW. The geological features of islands also influence their storage potential. While islands often lack space for large installations such as pumped hydro storage, they can use their coastline to employ technologies involving the storage of seawater. This centralised form of storage holds potential to store large amounts of energy while saving space. Further, pumped sea water circumvents the problem of limited fresh water supplies on islands which would be necessary for pumped hydro systems. However, it requires large investments that are often not feasible for smaller islands. Additionally, this technology requires special adaption from conventional pumped storage as it uses salt water, which causes corrosion. Due to its direct connection to the ocean, special mechanisms for the protection of marine life are essential as well.

The table below gives a short overview of storage technologies generally envisioned by island operators. This chapter's Section B presents several different storage projects implemented by island power managers.

Electricity Storage Technology	Features[28]	Purpose
Batteries	Batteries are best suited to reduce fluctuations through their fast response time, making them suitable for peak shaving and load levelling. They provide power at distribution substations for switching components and for substation communication and control equipment when the grid is not energised. Lead acid batteries have the main advantage of low cost, relatively good efficiency and very high availability in various application-specific products. However, they have quite low specific energy, a moderate lifetime, often include toxic materials, are temperature-sensitive and are globally outperformed by newer technologies. Newer technologies for batteries include the sodium sulphur battery (NaS). NaS batteries have a high energy density and are currently tested for frequency regulation and spinning reserve. A NaS project is presented in the case study chapter.	*Decentralised* *Short-term storage / balancing*
Flywheel	Flywheel electric energy storage systems store mechanical energy in a spinning shaft, which is connected to a motor or generator. During times of low demand, excess power is used to revolve the flywheel. In revolving, the mass builds up inertial energy. This kinetic energy is then released when the rotor is switched off, returning the kinetic energy to the electrical motor, which is used as a generator. Flywheels are able to deliver high power at a rather small capacity. Their main application lies in the time range of a few seconds up to a minute. A flywheel project is presented in the case study chapter.	*Decentralised* *Ultra-fast voltage regulation*

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[28] See EURELECTRIC position paper: Decentralised Storage: Impact on future distribution grids (2012); as well as Hadjipaschalis, Poullikkas & Efthimiou: Overview of current and future energy storage technologies for electric power applications (2011)

Electricity Storage Technology	Features[28]	Purpose
Pumped Hydro / Marine Hydro	Pumped storage hydropower stores electricity by pumping a large volume of water from a lower reservoir to a higher one in times of excess supply. When needed, the water is then released to flow back down through a hydro turbine, which generates power. Along with energy management, pumped storage systems help control electrical network frequency and provide reserve generation. Pumped storage plants, like other hydroelectric plants, can respond to load changes within seconds. Islands with a favourable coastline may also use pumped seawater storage, where the ocean acts as the lower reservoir. This technology demands special attention in dealing with salt water and the protection of marine life.	*Centralised* *Fast response or long-term storage of medium to large power quantities*

B. Benchmarks: Best practice

Following the general overview above, this section provides concrete examples of islands' moves towards more sustainable energy systems. The projects have all been realised by EURELECTRIC NEIS members or their partners and are presented including strategy and costs.[29]

Renewable energy projects

Close offshore & floating wind park on Malta

Offshore wind often offers strong and relatively constant wind speeds for power generation. Unfortunately, many remote islands face a challenge for offshore wind, in that water depth quickly increases relatively close to the coast. The Maltese have investigated solutions to overcome such challenges.

In 2009 the Maltese government initiated the development of a close-to-shore offshore 95MW wind farm, about 1.5 km off the coast. The project is set to contribute to achieving the national renewable energy share of 10% in gross final energy consumption for Malta according to Directive 2009/28/EC. Based on wind speed calculations, the wind farm would generate around 200GWh in one year. It is planned to be operational in 2016. Initial capital investment cost is estimated to be in the region between €280 and €335 million, financed through IPP.

To overcome the problem of great water depths, another project envisions the creation of a floating wind farm. In 2011 Hexicon Malta submitted a proposal for a floating offshore wind farm to the north-northeast of Malta. The water depth in this location is approximately 130m. Such a platform is innovative both in its design and construction; supposedly no other floating platform is capable of supporting as many turbines. Furthermore the entire construction will be capable of rotating, exploiting the best possible angle for wind speeds and directions. The proposed platform is built in a hexagonal shape with a total capacity of 54 MW. It is estimated to cost €200-250 million. The project will be financed through IPP, and is planned to be operational in 2014. (See Figure 9)

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[29] For more information on each project please contact the EURELECTRIC Secretariat.

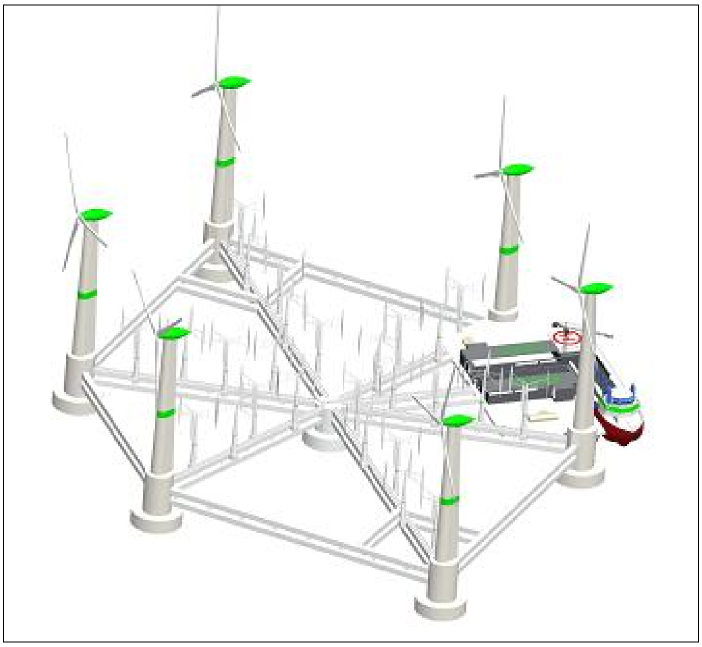

Figure 9: Floating deep offshore wind farm concept, Malta

50 MW parabolic trough power plant with thermal energy storage in Cyprus

The Electricity Authority of Cyprus is currently designing a solar thermal power plant of parabolic trough type, which is expected to begin operating in 2015. The solar field will include 640 parabolic trough collectors with a total net aperture area of 523,200 m^2. It is subdivided into four subfields, each with a cold and a hot heat transfer fluid (HTF) header. (See Figure 10)

The thermal energy storage capacity is designed with 850 MWh. The storage system will be charged through the heat transfer fluid. In good conditions the thermal energy storage will be fully charged within about 6 hours during the summer months. Given that the discharge will be done at the design values, the storage will be completely discharged within 7.5 hours.

The steam turbine’s gross efficiency will be 39.2% for day mode operation and 38.6% for storage mode operation. Gross electric power output will reach 50 MW in day mode and 44 MW in storage mode with a net electric power output of 43 MW in day mode and 39 MW in storage mode. The solar power plant is set to generate about 154 GWh of net electricity each year. Its annual capacity factor will be about 42%, which is equivalent to about 3,700 full load operating hours.

Total investment costs for the 50 MW solar thermal power plant are estimated at €360 million. The plant is currently under permitting evaluation by the Cyprus Energy Regulatory Authority and is expected to receive the relevant feed-in tariff in the near future. Financing is expected to be obtained from the European Investment Bank.

Figure 10: Parabolic mirrors of the solar thermal power plant, Cyprus

Geothermal energy in the Azores

Over a period of more than 35 years, geothermal power has become the most important renewable energy source in the Azores, consistently representing about 20% of the nine islands' electrical generation in recent years. Through the increased utilisation of geothermal power generation, the island group has additionally managed to take a large step towards energy self-sufficiency. The energy source is known for its reliability, which has enabled power operators to use it for base load generation, providing at times up to 56% of the power produced on the group's largest and most populous island São Miguel. In 2011, the production from the geothermal plants was 186 GWh, representing approximately 42% of the total energy produced on the island of São Miguel, and 22% of the total for the Azores Archipelago.

After the completion of first geothermal projects as early as the 1970s, geothermal power generation has continuously been expanded from small 500kW pilot projects to an installed capacity of 23MW from two plants in 2011. More potential capacity is being explored. Both power plants use the binary cycle, in which heat from geothermal fluid is used to heat and vaporise a working fluid which powers a turbine and condenses, to be re-heated and re-vaporised.

Considering the capacity presently installed on São Miguel and the anticipated development of the project on other islands of the group, geothermal energy is expected to account for close to 30% of power generation in the Azores in the near future. The role of geothermal power generation is expected to become even more significant in the Azorean electricity market, supporting the island group's contribution towards the achievement of the European renewable energy objectives.

Wind farm on the Faroe Islands

Onshore wind on the north European Faroe Islands enjoys very good potential. The small island group has a current installed wind capacity of 4MW, which produces up to 25% of the islands' power production at night. With 15 GWh of electricity production per year, the existing wind turbines make up 5% of the Faroe's total power production. Building on this, plans are being developed to expand the wind capacity by an additional 12 MW and to install storage capacity of about 4MW, which through latest control technologies could make up for intermittency issues. The new wind farm is scheduled to be connected by 2015 and is set to generate an additional 47GWh of green power per annum. Based on present oil prices the investment for the €19 million project has a payback time of about three to four years. (See Figure 11)

Figure 11: Wind farm, Faroe Islands

Sea water air conditioning for the north of Réunion Island

In 2010, the northern Saint Denis and Sainte Marie communities on Réunion Island set up an intercommunity to design, finance, develop and operate a cold production and district cooling network using deep seawater and "SWAC" (sea water air conditioning) technology. This network is intended to provide buildings in both communities with air conditioning. The infrastructure, which includes offshore and distribution networks as well as a pumping station, has been designed to deliver 40 MW, to be generated from seawater pumped up from great depths.

In the process, cold water will be taken from depths of more than 1,000m below the ocean's surface, 6 km off the coast. Circulating pumps will transfer the cold water to each client site's delivery substation, which is made up of one or several exchangers (seawater/freshwater). In addition to serving as a cooling installation, the infrastructure might be used by other sectors. The physical-chemical qualities of pure water extracted from great depths offer a wide field of new development opportunities for various applications mainly related to fish farming and aquaculture.

The cost of carrying out the studies and then building the SWAC is estimated at around €135 million. This will be covered by regional, national and European subsidies, in addition to the contribution from the successful bidder. The general economic structure of the public service delegation contract is based on income generated by sales of air conditioning to clients and on energy performance compensation. By utilising the SWAC system, its users can reduce the amount of energy used by stand-alone cold production facilities by more than 80%.

100% RES island El Hierro, Canary Islands

The government of the island El Hierro, in cooperation with the local utility and the Technical Institute of the Canary Islands, has embarked on a project that will allow it to meet El Hierro's electricity demand entirely by RES. This target is set to be achieved through a variety of measures, including a mixed system of electricity production. Main features are a wind farm with a hydroelectric power station (also used for the production of desalinated water for irrigation), the production of biogas from waste, RES installation in the residential sector and the introduction of an alternative transport system. In spring 2012 the project is in its last quarter of construction.

In addition, the plan seeks to implement corrective measures to preserve the landscape and to minimise the ecological impacts derived from the electric grid. A key issue for the project's success is energy storage. Project designers chose to rely on a hydroelectric pump-storage power station with a system of artificial lakes. The pump storage system consists of a 15 MW wind farm that harnesses wind energy to pump water to a reservoir. Once the reservoirs are full, the plant can supply irrigation water for the island's foothill farms, thus guaranteeing fruit and vegetable crops and providing forage for livestock on the island. (Picture see p. 32)

Another feature of the island's sustainable development strategy is the group of actions generated under the initiative "El Hierro – zero waste", which consists of the production of biogas by exploiting stockbreeding effluents and sewage for methanogen fermentation. To complete the sustainable approach, the Island Council has, in cooperation with the local transport cooperative, begun to take first steps to consolidate an alternative transport system, testing different hybrid and electric vehicle technologies for El Hierro.

Flexible conventional generation

Conventional generation must adapt to its new role as back-up support for an increasing share of intermittent electricity supplied by renewable sources. It needs to run more effectively on low loads, while employing abatement technologies to reduce emissions.

Flexible conventional generation plant with flue gas abatement in Malta

On Malta, a new modular and highly efficient combined cycle diesel engine plant has been installed. It is capable of operating both at base load and two shifting, while maintaining high conversion efficiency. Equipped with modern flue gas abatement technology, it can reduce emissions of nitrogen oxides (NOx), sulphur dioxide (SO_2) and particulate matter (PM). Through the application of waste heat recovery boilers, further capacity gains are achieved, while raising the plant's efficiency to 46.7% and reducing the fuel consumption per KWh generated.

The plant's diesel engines are capable of burning both heavy fuel oil and gasoil. Each engine is coupled to its own generator, while being enclosed in its own noise enclosure. Further noise reduction is achieved by applying noise cancelling material in the engine room and installing silencers.

Each of the eight engines is complemented by selective catalytic reactors (SCR) for NOx reduction, waste heat boilers, flue gas desulphurisation unit (FGD) for SO_2 reduction and a bag filter system for reduction of particulate matter emissions. A steam turbine utilises the steam generated in the waste heat recovery boilers. This modular layout ensures that the plant's efficiency remains close to its maximum value even at part load. To further lower the plant's emissions, all exhaust gases are passed through an emissions abatement plant. Through these processes, NOx reduction of 92% can be achieved.

The plant is also equipped with two fresh water generators using the waste heat in the engine cooling water as the main source of energy. This increases the efficiency of the plant since water produced may be used as a substitute for the main evaporator which operates on auxiliary steam from the conventional boilers.

A key to the plant’s enhanced flexibility relates to maintaining fuel circulation. The engines and their auxiliaries are kept hot during short shutdown periods. This process allows the fuel to continue to circulate within the system without the need for gasoil to restart. Further, the majority of the motors in the plant are equipped with a variable speed drive to minimise the losses incurred at reduced load by reducing the speed of the motor during such periods.

Energy from waste in Jersey

In 2008 the government of Jersey approved the construction of a new energy from waste (EFW) power plant as the largest capital project undertaken on the island, with project costs close to €130 million. It is scheduled to be fully operational by summer 2012.

The EFW is a critical infrastructure asset for the island to provide a safe, environmentally friendly method of dealing with the municipal waste and combustible solid waste generated on the island. The by-product of processing the waste is steam and this steam is used to power a conventional steam turbine and electrical generation unit with a 10MW generator.

The plant employs a two stream moving grate incinerator with heat recovery and gas cleaning. Emissions are controlled with a dry gas scrubbing system with activated carbon and lime injection and urea-based NOx abetment. When the combustion gases exit the boiler powdered lime and activated carbon are added to it in a venture reaction duct. The gas then passes through a bag filter system where the lime and carbon are recovered along with the particulates, acids and heavy metals in the gas. (See Figure 12)

The new installation is not the only plant in Jersey that generates power from waste. As part of the island sewage treatment process methane gas is produced as a by-product of the sludge digestion system. This gas can be used for electrical generation or as a heat source for other sewage treatment processes.

Figure 12: Construction of the 'Energy from Waste' plant, Jersey

Electric vehicle prospects on Jersey

Electric vehicles (commercial and domestic) offer an ideal solution to reducing oil imports and emissions from transport in a small island system – in particular as most domestic car journeys are only a few miles per day. With a dip in the island electricity load curve from midnight to around 6am, the charging of electricity vehicles provides a perfect solution for "off-peak" energy sales to improve the load curve, improve network utilisation and avoid system peak. With most observers expecting electric cars to enjoy significant growth over the next few years and linked to Jersey's ideal environment for electric cars (with short journeys), coupled with low carbon emissions and noise pollution from these vehicles, small islands like Jersey are ideally placed to take a leading role in the introduction of electric vehicles. Through its two subsea power cables connecting the island with the French mainland, Jersey's electric vehicles can be charged with imported low-carbon energy.

Local government are investigating different incentives to support customers in purchasing an electric vehicle. These range from dedicated parking places with charging stations to fiscal policy measures or cash subsidies. Estimated costs of such initiatives to the Government of Jersey are very low, as any time-limited promotion at the beginning of the introduction of electric vehicles will only be used by a small number of customers. More important are the clear signals that both the Government of Jersey and Jersey Electricity in partnership with the local car dealer network are committed to bringing electric vehicles onto the island.

Interconnectors

Malta–Sicily interconnector

Enemalta recently awarded a contract for the design and build of an HVAC interconnector between Sicily and Malta capable of continuously delivering at least 200MW at the receiving end in any direction at specified ambient conditions. The interconnector is planned to start operating before the end of 2013. The contract includes the construction of a 230kV substation at Maghtab in Malta together with all necessary switch gear, transformers and reactors to connect to the Maltese 132kV distribution system. The contract value is €187 million. There were multiple main reasons for the interconnector:

1. Security of supply
    - The electrical interconnection to Sicily will be completed by 2013, providing an alternative and geographically independent source of supply with:
        - Different typology of source
        - Different price drivers
    - The connection between Sicily and Italy is being strengthened by a 2 x 1000MW submarine 380kV HVAC system that is expected to be completed by 2014-15.

2. Operational advantages
    - Connection to a much larger system (UCTE) is expected to improve the voltage and frequency stability of a small and otherwise isolated system.
    - The connection will supply an appreciable overload capability that will improve stability of the local power system in case of local generation plant failure.
    - Local generating plant could be used more optimally to reduce emissions and improve local air quality.

3. Integration of large-scale renewable energy
    - For the planned 100MW offshore wind farm, there should be a sufficiently sized and flexible source to cater for the intermittent supply.
    - The interconnector is perfectly suited for such operation since it is connected to a much larger source – Sicily alone is expected to have 7,700MW conventional plant and 1,400MW wind energy.

Demand side management & energy efficiency

Millener project on French islands

French utility EDF has implemented a project focused on residential customers on several French islands. The project is set to collect information on customers’ behaviour and power demand and facilitate the integration of renewable energy through storage in residential homes. The collected information is used to develop ways for small systems to manage their power demand through e.g. peak shaving and to gain insight into customers’ responses to smart appliances for demand side participation.

The insights provided by the Millener project will shed light on possible solutions for many of the challenges small islands energy systems face. Next to ways of maintaining the balance between supply and demand in a small system, it is expected to offer solutions for dealing with intermittency and lowering overall consumption – both fundamental to sustainable energy development on islands. Currently, the project is being implemented in several islands within and outside of geographical Europe. As an example, 'Energy Management Boxes' were distributed on Corsica to enable first insights into demand side participation options. (See Figure 13)

Through the development of a renewable monitoring system, the improvement of forecast tools, the merging of smart storage operation and a better knowledge of the behaviour of individual customers, the project managers are aiming to prepare a system in which PV production and smart devices may become real contributors to insular system operation in the medium to long term.

Carried out by EDF in cooperation with a group of industrial partners, the Millener project is funded by the European Union, the Regional Councils of Corsica, Guadeloupe and La Réunion and the French government.

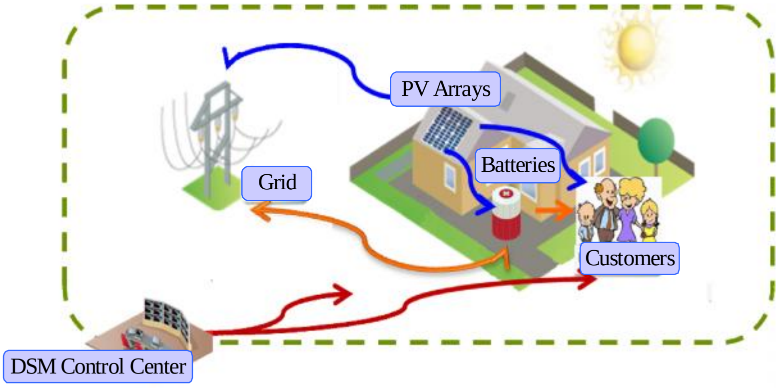

Figure 13: Combined PV and battery storage system (Millener Project)

Advanced metering infrastructure in Cyprus

The Electricity Authority of Cyprus is implementing a first phase implementation project aiming for the installation of 3,000 smart meters (Advanced Metering Infrastructure - AMI), including all required infrastructure. The initiative will provide the local stakeholders with an evaluation of the smart meter functionality, which will then be rolled out to cover the needs of the whole country, based on the results obtained. The main objective will be to determine operator requirements as well as the minimum functional requirements of an AMI system, including its architecture and its suitability and compatibility with different telecommunication technologies. The project will also give insights on the protocol and data communications standards best suited for smart meters and provide a basis for the development of a risk plan. To this end, three different smart meter types will be installed.

The AMI first phase implementation project is regarded as the precursor of the development of smart grids in Cyprus. Financed by the Electricity Authority of Cyprus, the project will be undertaken in 2012-2013. It is expected to cost less than €1 million.

Smart metering project in Malta

Enemalta Corporation has recently concluded a pilot project of 5,000 smart meters to prove the technical viability of a smart meter solution using an encrypted power line communication system for Malta. Since then, a total of about 140,000 smart meters have been installed, and it is expected that all electricity meters on Malta (260,000) will be changed to smart meters by the beginning of

2013 at a cost of €20 million. The smart meter deployment has been accompanied by a new billing system, which will be shared by the Maltese water utility, which is installing smart water meters, communicating through a dedicated and encrypted radio frequency network. When this project is completed in 2013, Malta will be one of the first countries with a 100% smart meter deployment for both water and electricity and one of the first where combined billing for both water and electricity is based on automatic readings from smart meters.

Since Malta relies for up to 50% of its water supply from sea water desalination, the consumption of such water represents a significant energy cost. The use of smart water and electricity meters and smart billing together will enable consumers to better manage their overall energy consumption.

The Malta smart meter project, together with the newly installed HV system SCADA, is considered to be the core of the future Maltese smart network, with the ability to monitor and control loads on a continuous basis. Already all distributed generation on the island (mainly small RES) is connected and monitored through the smart meters.

Energy efficiency programme in the French Caribbean

To increase energy efficiency for residential consumers, EDF organises and funds sell-through markets of efficient appliances such as energy saving lamps, automatic standby plugs and water-saving devices (to minimise the power needed to produce hot water). Residential consumers are also induced to install solar water heating or insulate their houses.

Commercial and industrial consumers as well as administrations are encouraged to reduce their air-conditioning consumption by improving building insulation, solar protection (roof expansion, better reflectivity) and installing efficient air-conditioning equipment. Further, industrial customers are offered specific solutions (motor with electronic speed drive, cogeneration). If equipped with diesel generators, they can also contract with EDF to switch their consumption from the grid to their generator on request. This process will be automated and centralised by the smart grid project SIGMA, which is currently under deployment.

In addition, the utility is planning to roll out smart meters on French island territories ahead of their introduction in mainland France. The project features automated meter reading and supervision as well as enhanced customer information through web portals and local displays.

EU-EcoGrid on Bornholm

Realised with about 50% EU funding through the EU's 7th Framework Programme, the Danish island of Bornholm embarked on the 'EcoGrid' project. With a total budget of €21 million, the idea of the project is to introduce market-based mechanisms close to the operation of the power system that will release balancing capacity, particularly from flexible consumption over a period of four years.[30]

The system comprises about 28,000 electricity customers and has very high penetration of a variety of low-carbon energy resources, including wind power, combined heat and power, active demand, photovoltaic and electric vehicles.

In total 2,000 households on Bornholm will show how Europe can manage a system with over 50% wind power and other fluctuating and less predictable renewable sources by means of more flexible consumption. (www.eu-ecogrid.net)

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[30] See www.eu-ecogrid.net

Storage

Pumped hydro storage in the Canary Islands

Due to their geographical position and geological features, the Canary Islands have developed a storage project which will allow for a much larger share of RES penetration on their market after 2017. The relatively high terrain levels on Gran Canaria host enormous potential for pumped hydro storage, which will be utilised with a closed-loop pumped storage power plant. The site is planned to feature three power turbines with a combined capacity of 201MW (210MW in pumping configuration), achieved through utilising a gross head of water of more than 370 metres, taking full advantage of the island's geological features. The €290 million investment will be carried in full by the Enel-Endesa holding.

Flywheel in the Azores

A different approach to small system storage solutions is being carried out on the Azores. In an effort to find solutions to maximise the energy production from renewable sources, but also to improve grid stability and the efficiency of diesel engines, EDA developed a project to integrate flywheels into the electrical system. The flywheels were set up in 2005-2006. At that time, the project was one of the first applications in the world of this technology on island power systems. (See Figure 14)

Flywheels are able to store kinetic energy and – using AC/DC power converters to connect to the grid – to maintain control and power grid stability. The main advantages of the flywheel solution compared to other energy storage systems are the high charge and discharge cycles, with variable time intervals between them. Flywheels can therefore attenuate the grid instabilities induced by wind energy production, thereby making an increased penetration of renewables possible while maintaining the quality of supply on the grid.

Figure 14: Flywheel storage unit outside a power station, Azores

Pegase: Small storage & RES generation forecasts on Réunion

Increasing the RES penetration was the main reason behind a project on Réunion which uses fast-response energy storage facilities. The so-called Pegase demonstration project was launched in 2011 to tackle grid stability issues caused by a large-scale PV and wind power generation system connected to the grid. Carried out in cooperation with the French national meteorological agency and dynamic meteorological laboratory, it builds on an earlier project from 2006-2009, exploring the use of energy storage technology to increase the flexibility of the electric system. The aim was to install and commission 1MW of sodium sulphur (NaS) energy storage on Réunion Island.

The NaS battery is capable of storing about 7.2 MWh of electricity. Since December 2009, the battery has done more than 550 cycles, delivering ca. 2.3 GWh to the grid. It is used for daily load shifting on the island, with charging during night and afternoon and discharge in the evening and at noon during summer. The project aims to test the capability of a NaS battery to back up newly installed PV farms and a wind park, through day ahead and intraday forecasts. Additionally, it will be tested to supply frequency regulation and spinning reserve.

The demonstration project will also investigate new methods for day-ahead RES generation forecasts. A statistical model will be developed, based on historical solar power generation data along with weather forecasts. Performances will be analysed in terms of forecasting errors and compared to those obtained by a reference model. Further, the project seeks to test a new method to forecast intraday PV generation. It will explore different ways of calculating such forecasts (up to 3 hours) by on-site sky imager and satellite image, along with image analysis and RES production records. The plan also features the installation of real-time meteorological sensors and a sky imager network surrounding the island to generate data for analysis.

Through the implementation of smart software, the system will fine-tune a number of operational obstacles such as dispatch constraints like maximising evening production, minimising impact of RES generation forecast error and managing long-term storage. With the lessons learnt, Pegase directors are confident that the project's approach to forecasting and result optimisation could be applied to other small-scale RES systems. (See Figure 15)

Figure 15: Weather monitoring at a PV power station (Pegase Project)

SEPMERI: Sea water pumped storage on Guadeloupe

In the frame of the 2011 call for proposal on 'Energy storage', launched by the French Environment and Energy Management Agency, EDF is planning a 50MW pumped seawater project called SEPMERI.[31] Working similar to a regular pumped hydro storage plant, but with Sea water, this project aims to build an upper reservoir with a capacity of 8 Mm 3 allowing 1 GWh storage and a 20 hour time duration service at full load. The project could allow the penetration levels of RES generation above 30%, while persevering system stability and security for island systems.

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[31] Stockage d'Energie par Pompage en Mer permettant le développement des Energies Renouvelables Intermittentes

Due to its geologic advantages, the Caribbean island of Guadeloupe is currently in the focus of the project, offering a favourable coastal line for the installation of the pump storage facility. Due to the novelty of the specific concept, the project is currently classified as a pilot RD&D effort. For the undertaking, EDF formed partnerships with equipment suppliers and universities with funding support from local authorities. With further financial support from French and European sources, project managers aim to achieve a funding level of up to 30% of the project costs.

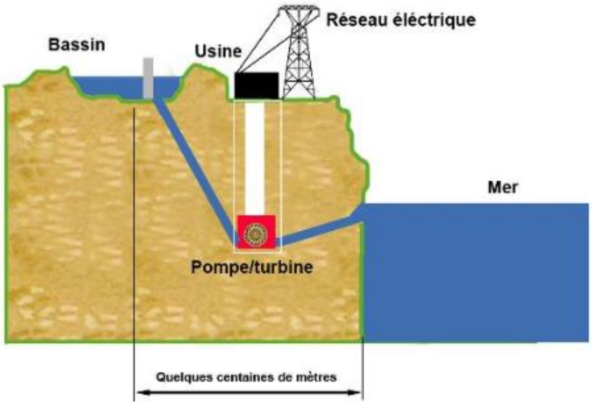

Figure 16: Simplified cross section of a sea water pumped storage plant

Towards an EU Island Action Plan 2020

Four Recommendations

This report has highlighted that island energy systems, despite their diversity, share common characteristics and are thus subject to common challenges. Their sustainable energy future depends on an improved investment climate and policy framework. In many cases, the limited size of their markets raises issues of market failure: complementary measures and remedies have to be found.

The following recommendations are made to both national and European policymakers, in order to incentivise the transition towards a sustainable energy future. The recommendations should be part of an EU Island Action Plan 2020, which would bring the islands' trajectories in line with the overall EU 2020 project.

1. **Set up an EU Island Sustainable Energy Action Plan 2020**

EURELECTRIC recommends establishing an island action plan, to be jointly set up by the European Commission's DG Energy and DG Regional Policy. The plan should contain island-specific measures up to 2020. Islands are part of the EU and should be part of the EU's ambitious 2020 strategy. A comprehensive 2020 framework has yet to be set up.

2. **Improve security of supply through diversified power generation technologies and interconnection**

Systems that are over-dependent on one single technology (like oil-based power generation) are vulnerable, as last year's incident at the Cyprus Vasilikos power plant incident has shown. The EIB support for switching that plant's power generation from oil to gas is an appropriate answer. There is a need to encourage diversification towards low-carbon power generation. Interconnection, where feasible, is an important tool to limit exposure to such incidents.

3. **Use islands as a priority test-bed for innovative technologies such as storage, smart grids and RES. Foster RD&D on islands.**

Islands and isolated systems have the potential to demonstrate new energy systems and technologies. This potential should be used and incentivised through RD&D support, especially for renewable and enabling technologies such as energy storage. This will improve the situation of island power systems, while the mainland could learn and benefit from the demonstration of new technologies.

4. **Use exemptions appropriately and address the market failures that occur as a result of limited size and isolation.**

EURELECTRIC, which favours market-based mechanisms, acknowledges the need for an appropriate, carefully chosen response to the markets failures that often occur as a result of islands' small size and isolation. Such a response should opt for the least distortive measures, like RD&D support. A specific market design and investment incentives for low-carbon technologies are needed to use islands as test-beds for new technologies and put them on a sustainable, low-carbon track.

Annex

This annex comprises main data tables from a questionnaire distributed among EURELECTRIC members in early 2012. An interactive map with downloadable tables is available on the EURELECTRIC website.[32]

Azores:

Population: 246.000

GDP 2010: € 3, 7 billion

Unemployment: 11.7% (2011)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak dem. (MW)						
Santa Maria	3	4	4	4	4	5
Sao Miguel	72	74	74	74	73	72
Terceira	36	36	38	40	36	39
Graciosa	2	2	2	2	2	2
Sao Jorge	4	5	5	5	5	5
Pico	7	7	8	8	8	9
Faial	9	9	9	9	9	9
Flores	2	2	2	2	2	2
Corvo	0.2	0.3	0.2	0.2	0.2	0.4
Total dem. (GWh)						
Santa Maria	18	19	19	20	20	25
Sao Miguel	394	407	407	418	414	425
Terceira	186	193	192	198	195	200
Graciosa	12	13	13	13	13	12
Sao Jorge	23	25	26	28	28	28
Pico	38	39	40	42	43	48
Faial	45	47	47	48	47	46
Flores	11	11	11	12	11	12
Corvo	1	1	1	1	1	2

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	580	605	613	610	587	392
Renewables						
Hydro	31	25	22	31	33	50
Solar				0.02	0.03	0.09
Wind onshore	16	22	31	34	33	83
Wind offshore						
Biomass						53
Geothermal	178	170	162	174	186	289
Other	0.2	0.03	0.1	0.3	0.3	0.4

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**	3.434	4.413	4.411	2.723	1.521
Nitrogen Oxides **NOx**	5.890	6.412	9.100	10.408	8.471
Carbon Dioxide **CO2**	383.418	405.258	408.805	403.579	385.941

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[32] See http://www.eurelectric.org/Maps/InteractiveMapIslands/

Canary Islands:

Population: 2.127.000

GDP 2010: € 40, 34 billion

Unemployment: 32.2% (2012)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)						
Gran Canaria	600	582	582	571	563	734
Tenerife	595	587	550	569	580	738
Sistema LZ-FV	260	267	248	257	243	327
La Palma	45	45	45	48	46	59
La Gomera	12	12	12	12	12	16
El Hierro	7	7	7	7	7	10
Total demand (GWh)	**9215**	**9341**	**9126**	**8886**	**8862**	**11597**
Gran Canaria	3667	3712	3626	3527	3510	4617
Tenerife	3644	3712	3626	3525	3506	4580
Sistema LZ-FV	1535	1538	1502	1451	1477	1916
La Palma	262	269	262	268	255	334
La Gomera	67	70	69	72	71	94
El Hierro	40	42	41	43	43	56

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	8819	8869	8592	8345	8269	2325
Natural Gas						6855
Renewables						
Hydro (*)	1	2	0	0	2	-159
Solar	19	76	168	194	237	334
Wind onshore	375	390	358	339	348	2042
Wind offshore						
Biomass						31
Other	0	3	7	8	6	168

Hydro (*): Energy balance including pumped storage.

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**	16.103	15.368	15.500	14.742	11.307
Nitrogen Oxides **NOx**	42.463	41.209	44.606	30.681	37.834
Carbon Dioxide **CO2**	6.607.603	6.528.886	6.219.732	6.149.202	6.084.878

Corsica:

Population: 311.000

GDP 2006: € 7 billion

Unemployment: 8.3% (2009)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	443	434	464	489	463	600
Total demand (GWh)	1898	2019	2087	2212	2130	2771

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	1006	861	939	894	1074	
Natural Gas						
Renewables						
Hydro	253	500	483	580	294	
Solar	0	0	0	2	25	
Wind onshore	33	34	29	27	24	
Wind offshore						
Biomass						
Biogas			6	9	8	
Interconnections	606	624	630	701	705	

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**					
Nitrogen Oxides **NOx**					
Carbon Dioxide **CO2**					

Cyprus:

Population: 804.435

GDP 2010: € 17, 8 billion

Unemployment: 8.5% (2011)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	1056	1010	1103	1105	862	1575
Total demand (GWh)	4786	5049	5178	5380	5305.8	7365

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	4850	5049	5178	5211	5327	500
Natural Gas						5765
Renewables						
Hydro						
Solar	1	3	3	5	10	528
Wind onshore				31	114	494
Wind offshore						
Biomass		1	20	25	40	150
Other						
Interconnections						

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**	33.423	33.108	33.634	34.170	34.715
Nitrogen Oxides **NOx**	7.481	7.560	7.790	7.953	8.119
Carbon Dioxide **CO2**	3711.139	3856.337	402.5148	4193.042	4374.247

Faroe Islands:

Population: 48.372

GDP 2010: € 1, 7 billion

Unemployment: 1.3% (2008)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	48,3	52,2	52,1	51,2	48,0	55
Total demand (GWh)	269,4	275,8	275,5	280,3	273,8	330

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	149	167	168	199	167	100
Natural Gas						
Renewables						
Hydro	104	96	92	67	93	120
Solar						
Wind onshore	16	13	15	14	15	87
Wind offshore						
Biomass						
Other						23
Interconnections						

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**	580	677	693	798	681
Nitrogen Oxides **NOx**	2.203	2.494	2.505	2.982	2.518
Carbon Dioxide **CO2**	100.761	112.583	116.941	131.545	111.057

Guadeloupe:

Population: 404.000

GDP 2006: €7.75 billion

Unemployment: 22.6% (2011)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	241	242	248	260	256	325
Total demand (GWh)	1609	1612	1653	1730	1692	2173

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal	328	344	220	281	514	
Oil	1045	1047	1242	1300	973	
Natural Gas						
Renewables						
Hydro	20	22	21	16	15	
Solar	2	3	5	17	33	
Wind onshore	44	49	51	41	45	
Wind offshore						
Biomass	75	58	64	60	55	
Geothermal	95	89	50	15	56	
Interconnections						

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**					
Nitrogen Oxides **NOx**					
Carbon Dioxide **CO2**					

Guernsey, Channel Islands:

Population: 62.451

GDP 2010: £ 1, 93 billion (ca. €2, 35 billion)

Unemployment: 1.1% (2011)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	76.3	75.2	78.6	85.0	78.3	76.3
Total demand (GWh)	363.685	377.107	387.241	398.020	381.212	363.685

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	127	113	195	101	75	
Natural Gas						
Renewables						
Hydro						
Solar						
Wind onshore						
Wind offshore						
Biomass						
Other						
Interconnections	237	264	193	297	306	

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**					
Nitrogen Oxides **NOx**					
Carbon Dioxide **CO2**	75.300	116.800	102.200	56.800	

Isle of Man:

Population: ca. 80.000

GDP 2010: £ 3.4 billion (ca. €4, 14 billion)

Unemployment: 2.3 % (2012)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	91	91	91	94	90	90
Total demand (GWh)	428	440	435	438	426	426

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	10.5	15.1	8.5	10.3	10	10
Natural Gas	404	465	507	477	443	450
Renewables						
Hydro	2.3	3.5	3.1	2.8	3	3
Solar						
Wind onshore						
Wind offshore						
Biomass						
Other	22.3	13.9	28.4	25.4	24	25
Interconnections (Imports)	43.1	32.5	12.6	29.6	53	40
Interconnections (Exports)	54.7	89.9	125.2	106.9	108	110

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**					
Nitrogen Oxides **NOx**					
Carbon Dioxide **CO2**	174.000	200.000	207.000	201.000	187.000

Jersey, Channel Islands:

Population: ca. 91.000

GDP 2010: £ 3.5 billion (ca. €4, 26 billion)

Unemployment: 4.7% (2011)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	142	156	153	158	154	183
Total demand (GWh)	608	639	642	645	651	813

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	66	20	42	38	12	8
Natural Gas						
Renewables						
Hydro						
Solar						
Wind onshore						
Wind offshore						
Biomass						
Other	3	4	6	4	17	41
Interconnections (Imports)	539	615	594	603	622	764

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**	276	141	349	270	233
Nitrogen Oxides **NOx**	477	343	490	401	446
Carbon Dioxide **CO2**	83,940	49,594	60,591	65,591	36,955

Malta:

Population: 417.608

GDP 2010: €4, 7 billion

Unemployment: 6.8% (2012)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	434	424	403	400	414	457
Total demand (GWh)	2296	2185	2048	1994	2046	2311

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	2296	2185	2046	1991	2043	968
Natural Gas						
Renewables						
Hydro						
Solar		0.4	2.8	2.9	3.1	49
Wind onshore						24
Wind offshore						250
Biomass						120
Other						
Interconnections (Imports)						900

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**	12.387	10.440	7.846	8.140	7.773
Nitrogen Oxides **NOx**	5.538	5.600	5.269	5.083	3.959
Carbon Dioxide **CO2**	2.027.364	2.019.000	1.897.000	1.878.300	1.931.480

Martinique:

Population: 403.000

GDP 2010: €7, 9 billion

Unemployment: 21.9% (2011)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	235	237	239	242	241	328
Total demand (GWh)	1488	1530	1550	1617	1576	2095

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	1452	1492	1506	1573	1521	
Natural Gas						
Renewables						
Hydro						
Solar	3	5	12	19	38	
Wind onshore	1	1	2	1	1	
Wind offshore						
Biomass						
Waste	32	31	31	24	15	
Interconnections (Imports)						

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**					
Nitrogen Oxides **NOx**					
Carbon Dioxide **CO2**					

La Reunion:

Population: 824.000

GDP 2008: €14, 7 billion

Unemployment: 29.5% (2011)

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	404	408	423	429	442	574
Total demand (GWh)	2461	2546	2618	2699	2750	3617

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal	1253	1287	1247	1315	1305	
Oil	298	339	519	473	613	
Natural Gas						
Renewables						
Hydro	658	633	531	542	402	
Solar	4	11	21	76	142	
Wind onshore	10	14	15	17	12	
Wind offshore						
Biomass	238	263	278	269	270	
Biogas			7	8	6	
Interconnections						

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**					
Nitrogen Oxides **NOx**					
Carbon Dioxide **CO2**					

Tahiti (outside EU regulation):

Population: 267.000

GDP 2010: €4.5 billion

Unemployment: NDA

Power Sector main indicators:

Demand

	2007	2008	2009	2010	2011	2020
Peak demand (MW)	97.6	94.6	101	101.4	90.9	109
Total demand (GWh)	622	619	635	636	605	718

Power generation mix (GWh)

Fossil fuels	2007	2008	2009	2010	2011	2020
Coal						
Oil	516	534	553	487	484	576
Natural Gas						
Renewables						
Hydro	175	157	155	220	181	186
Solar	0.04	0.05	0.05	0.3	4.5	16
Wind onshore						
Wind offshore						
Biomass						
Biogas						
Interconnections						

Total emissions from Power sector (tons)

	2007	2008	2009	2010	2011
Sulphur Dioxide **SO2**	3.500	3.640	3.140	2.010	2.040
Nitrogen Oxides **NOx**	7.230	7.480	7.750	6.330	6.280
Carbon Dioxide **CO2**	375.000	388.000	401.000	354.000	352.000

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