HOW TO APPLY GREEN TECHNOLOGIES IN A HARBOUR SETUP

E-Harbours towards sustainable, clean and energetic innovative harbour cities in the North Sea Region

The Interreg IVB North Sea Region Programme
Investing in the future by working together for a sustainable and competitive region

pure ENERGY CENTRE

ACKNOWLEDGEMENT

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GLOSSARY

CO_2	Carbon Dioxide Gas
kWh	kilowatt hours of energy
MWh	Megawatt hours of energy (1MWh = 1000kWh)
GWh	Gigawatt hours of energy (1GWh = 1000MWh)
t	Metric Tonne
m^2	Square meter
l	liter
NSR	North Sea Regions
VPP	Virtual Power Plant
EU	European Union
ICT	Information and Communication technology
EV	Electric Vehicle
HEV	Hybrid Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
CAPEX	Capital Expenditure
OPEX	Operating Expense
PV	Photovoltaic
SWH	Solar Water Heating
EfW	Energy from Waste
WT	Wind turbine
H2O	Water
H_2	Hydrogen
O_2	Oxygen
CHP	Combined Heat and Power
GF	Green Fuel

EXECUTIVE SUMMARY

This report has been carried out as part of a pan European project called **E-Harbours, E-Logistics in NSR Harbour Cities**, awarded by the Interreg IVB North Sea Region Programme.

This report attempts to illustrate how to use the different technologies described in Report 2 into a harbour setup. A single scenario is described for each of the following technologies:

- Smart grids
- VPP
- Electric mobility
- Green technologies

The report provides a means to understand how to apply the above technologies in a real life set up by giving a set of examples. After reading this report, harbours designers, operators, planners, city harbour owners and harbour entities will therefore be able to define which of the energy technology described in Report 2 can be best used in and within a given harbour setup, but also, **and more importantly,** how to apply it effectively. By using effectively the outcomes of this report, any harbour user or entity will be able to reduce their hydrocarbon dependence, leading to a better control of their energy costs, thereby become more competitive, locally, regionally, nationally and internationally.

In summary, this document will play an important part into the E-Harbours project and for the harbour community by showing how to use and apply technologies described in Report 2 in a real setup. It will provide key background information to any harbour design and modification leading to the better management of resources, in, and within a harbour compound.

KEY FINDINGS

- A harbour set up is ideal for the use of smart grids.
- Smart grids can manage the complex harbour electrical network and operate appliances only when there is enough renewable energy generation.
- Smart grids can minimise the energy cost by shifting the electrical consumption during periods with lower energy tariff.
- Virtual power plants can manage power generation systems located at different sites in Shetland.
- Each VPP system using renewable power must be backed up by a standard generation unit.
- Each harbour's organisation is connected to the grid network of the harbour; therefore, each company has the potential to install an electric vehicle charging point.
- Small to medium harbours with activities mainly centralised during daytime can benefit from charging battery vehicles during the night period when energy cost is lower.
- Large scale harbours with activities on a 24/7 operation require a spare set of charged

battery banks to replace the deemed discharged onto electrical vehicles and guarantee the full operation.

- The use of PHEV allows harbour business operators to benefit from cheap charging tariff when the vehicle does not operate and from quick refuel of the petrol type engines.
- Harbours can accept the installation of a marine generation unit on the breakwater, wind turbines on the available development land and both Solar PhotoVoltaic (SPV) and/or Solar Water Heating systems (SWH) on business roofs.
- During over generation of electricity from renewables, the excess power can be stored instead of shutting down some of the generation units.
- The electricity storage suitable for harbour environment is battery banks, electric vehicles (storing the energy in the batteries) and flywheels.
- The storage of heat in a harbour environment could be either in dry or wet storage systems.
- The stored energy can be used to produce green fuel as a form of hydrogen (from water) or ammonia.
- There are many European-wide and UK-wide set of financial support schemes for renewable energy. These financial schemes are clear incentives for harbours to become more energy efficient and pave the way in renewable energy and energy storage technologies.

TABLE OF CONTENTS

INTRODUCTION

This report aims to provide and disseminate how to use the technologies described in Report 2. The objective of this report is unique as it will provide the harbour community with a means to understanding how to apply the latest energy technologies in a harbour and how this can lead to the introduction of a novel energy mindset. The ultimate goal is to widely disseminate information on some of the energy technologies that can be applied in a harbour so that, in the future, this can support other harbours at NSR, European level and beyond.

Through this report, harbour masters, harbour owners, harbour policy makers and harbour business organisations will be able to learn and apply an effective energy technology deployment. This will support them to identify which energy technology they can use, in which case they can use it and how to use it with great effectiveness to reduce their consumption and emissions.

This report is therefore divided into two (02) main sections. The first section of the report provides the aims and objectives of the report. The second section describes how to use state-of-the-art energy technologies in a harbour set up. This section consist of (04) subsections. The first subsection aims to show how to use smart grid concepts in a harbour set up. This is following by a subsection describing how VPP can be applied in a harbour. The third subsection illustrates how to use E-Mobility which is then followed by a subsection describing how to use renewable energy and green fuel technologies.

AIMS

The E-harbours Project as a whole aims to create a lasting change towards sustainable energy logistics for North Sea Region harbour cities. It aims at setting innovative energy standards to create a transformation of the energy network in harbour areas.

This report intends to increase the understanding of harbour owners, business and other entities related to harbours regarding how to use latest energy technologies to control and monitor energy within a harbour set up. This summarises a number of examples as to how to use the technology described in Report 2.

The examples described can be used by decision makers in any other European harbour and beyond to develop the future harbour's energy systems.

The examples are universally applicable to any small, medium and large harbour, but in certain instance focused on the Scalloway harbour.

Of key significance, the report has been developed to support the development of an effective energy harbour system and will lead to better decision making and better investment priority in renewable energy, smart grid and electric vehicle technologies.

OBJECTIVES

After reading this report, the reader should be able to:

1. Understand how to apply smart grids, VPP, electric mobility and green technologies in a harbour set up.

2. Devise plans for the deployment of green technologies in a harbour.

3. Have a clearer understanding of the interaction between the technologies described in Report 2 and how they interact with each other in a real life type scenario.

4. Devise and prioritise a harbour investment in renewable energy, smart grid and electric vehicle technologies.

HOW TO USE STATE-OF-THE-ART ENERGY TECHNOLOGIES IN A HARBOUR SETUP?

The sections below summarise how to apply some of the technologies described in Report 2 in a harbour set up. The example of technology applications are as follows:

- Smart grids technology
- Virtual Power Plants
- Electric mobility
- Renewable and green fuel technologies

HOW SMART GRID CAN BE APPLIED IN A HARBOUR ENVIROMENT?

As described in Report 1, 'The energy issue with harbours, Case study - The Scalloway harbour', many different companies/organisations, such as fishing companies, ice making companies and others operate in a harbour environment. Each and every one of these companies is connected to the grid network of the harbour (called here the harbour network), which itself is connected to the national grid network. Therefore, the harbour network could be looked at as a small grid network connected to a larger grid network. This is shown in Figure 1.

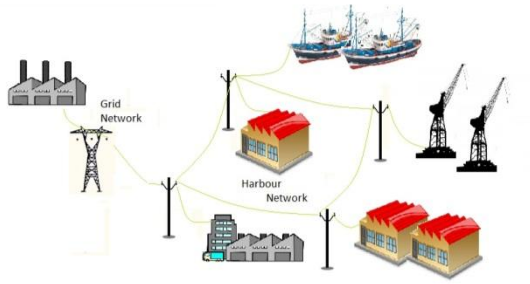

Figure 1 – Internal harbour grid network and national grid network

Looking solely at the harbour grid network and assuming that all organisations within the harbour have installed solar power systems on top of their roof facilities, (see below section on solar photovoltaic) now assume that one wants to switch on one fridge (or heater, or a process, or other) **only** when there is power generated from the solar power system. To do this, a 'system' is needed that allows detection of generation from the solar power installation. The 'system' would need to be capable of identifying if there is enough power from the solar installation. If solar power generation was not high enough to supply the heater, then the 'system' would not switch on the heater. However, if the 'system' detected that there would be enough power to supply the heater, then the heater would be switched on.

Now suppose that there was enough power for switching on one heater and that suddenly there is enough solar power to supply another three (03) heaters. The 'system' would be capable of detecting (monitoring) the power generated by the solar installation and then switch on (control) the extra three heaters. In addition, the system would be able to manage any future fluctuation in the power generation by switching on and off heaters or other appliances /processes.

From the aforementioned, one can see that even a small harbour 'system' connected to a set of distributed generation can become very complex when taking all of the different variables into account. The 'system' referred to above is simply a smart grid system. This is why and how a smart grid system can benefit harbours of any size, especially when there is distributed generation.

A smart grid system can also benefit a harbour in other ways, for instance by using and benefiting of the electricity billing tariffs. It is known that there are now several different tariffs for purchasing power. For simplicity one would use only two tariffs, the daytime tariff and the night time tariff. It is widely known that the nigh time tariff is cheaper than the day time tariff. Therefore a smart grid system could be installed in a harbour set up to automatically operate appliances such as large freezers at night and only switch on the freezers during the day for maintaining the internal freezer temperature within preset limits. This would allow for the reduction of electricity bills, leading to the better and more effective management of a company's wealth and resources.

From the above, one can conclude that smart grids can be applied in many different forms within a harbour set up and that smart grids can provide a means to reduce a harbour's organisation expenditures .

A harbour environment is ideal for a smart grid system

HOW VPP CAN BE APPLIED IN A HARBOUR ENVIROMENT?

There are many different ways that a harbour can benefit from a VPP system. First one needs to identify the availability of power generation sites such as diesel generation, land available (or renewables) or sea resource available (for marine power generation).

For instance, Shetland has many small to medium harbours. Each of these harbours have either facilities (businesses or others) located on the harbour site, or nearby land available for future developments and all of the harbours are connected in one way or another to the sea.

Looking at any of the Shetland's harbour geography, marine current turbines can be installed at many harbour sites. In the case this is not possible, wind generation can be installed and at a third harbour site a tidal device put in. In Scalloway harbour a number of solar panels can be installed locally, while a set of wind generators as well as more solar systems can be installed at another site (the site would belong to Scalloway harbour or rented by Scalloway harbour).

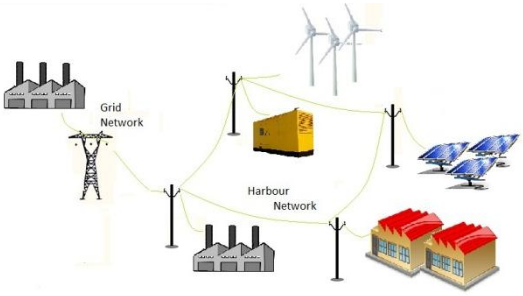

Figure 2 – A VPP network with distributed power generation

Figure 2 illustrates an example of a VPP. The wind generation and solar generation are located outside the Scalloway harbour, but controlled through a localised management system (in this case the localised management system is the VPP).

In essence, for a VPP to take form, most of the power generation systems are located at different sites. The VPP is then used to control the different generation systems. In this case, a smart grid would send requests to the VPP for a given generation requirements and the VPP would switch on or off the required resource.

The difficulty with the aforementioned VPP scheme can be found in the use of renewable sources of power. Unfortunately, each VPP system using renewable power must be backed up by a standard generation unit. A standard generation unit is a system that uses diesel generators, gas turbines, the national grid or others. The rational is that when a renewable resource is not generating power, then a diesel generator would need to be switched on to provide power to the load demand. This is in effect a diesel back up power.

VPP can manage power generation systems located at different sites

HOW ELECTRIC MOBILITY CAN BE APPLIED IN A HARBOUR ENVIROMENT?

As described in report 1, ‘The energy issue with harbours, case study - The Scalloway Harbour’, many different companies/organisations, such as fishing companies, ice making companies and others operate in a harbour environment. Many of these companies own forklifts and business type vehicles (delivery vans, small trucks to larger transport applications). These vehicles emit a substantial amount of emissions at the point of use and requires refuelling, gas supply, oil based fuel or other means for fuelling their fleets.

Each and every one of the harbour’s companies is connected to the grid network of the harbour (called here the harbour network). Therefore, each company has the potential to install an electric vehicle charging point (see Figure 3).

In most small to medium harbours, the activities are mainly centralised during the daytime.

Therefore, the electric vehicles would mainly operate during day time. This is very suitable for the harbour companies as they would be able to maximise their fleet fuel costs. As electricity is more expensive during the day, most of the battery vehicle charging would occur at night. The cost of electricity being cheaper than the cost of fuel, a harbour business would therefore reduce its outgoings. Obviously, on a number of occasions, there will be a need for daytime battery charging. In these cases, only top-ups would occur to recharge the battery to a level that the vehicle can operate. Using this scenario, the companies would be able to operate efficiently, see their fuel outgoings reduced and negotiations with the grid owner could be undertaken to get preferential tariffs if a VPP or smart grid is used in conjunction with the 'dumping load', that is the electric vehicles.

Figure 3 – Charging point for electric forklift[1].

The above scenario may not be applicable in large scale harbours. For instance, a large scale harbour would need 24/7 operation, which means that there will be a need for a solution to the battery charging requirements. One of such solution being used nowadays is to have two banks of batteries for one vehicle. When one bank is deemed discharged, then this battery would be removed from the vehicle. This would be put to recharge and replaced by its counterpart charged battery bank. Another solution would simply be to use PHEV, which would allow the harbour business operators to benefit from cheap charging tariff when the vehicles do not operate (at night) and to take advantage of the petrol type engines for quick refuel.

Other scenarios can be drawn for each of the harbour requirements, as long as the requirements are summarised and not to be modified during implementation/operation of the fleet.

[1] http://www.timesunion.com/business/article/Warehouse-is-up-and-operating-1382394.php

HOW RENEWABLE ENERGY AND GREEN FUEL CAN BE APPLIED IN A HARBOUR?

There are many different ways renewable energy technologies and green fuels can be applied in a harbour setup. A typical example to illustrate how a harbour can benefit from these technologies is to take a harbour with many building facilities, availability of development land and a long breakwater system with good wave and tide potential (or even current potential).

Looking at the above proposed harbour, one easily anticipates the installation of a marine generation unit(s) on the breakwater. The available development land could be used to install wind turbines. The harbour's business roofs would be used to install both Solar PhotoVoltaic (SPV) and/or Solar Water Heating systems (SWH). The installation of an SPV or SWH on top of a business roof would depend on the particular needs of the business. As described in 'report 1' some harbour's businesses requires substantial heat while other requires electricity (and sometimes both heating and electrical power). Hence, each solar system installation would need careful consideration.

It is clear from the above that when all the power generation units (wave, wind, solar) operate at the same time, that there could be over generation. Over generation occurs when there is excess power generated and there is not enough demand. Instead of shutting down some of the generation units, the harbour would be best to install energy storage systems in the form of electricity, heat and fuel, through fuel generation units. The electricity storage would be battery banks (large or small), electric vehicles (storing the energy in the batteries), flywheels, and other form of electrical storage. For storing the heat, either dry or wet storage systems could be used. Finally, storing energy as fuel could take the form of hydrogen (from water) or ammonia (or both).

In all of the above storage cases, the harbour could modify its operation/logistics to sustain a renewable energy storage system, fully geared to reduce outgoings and increase income to the harbour entities.

The current European wide and UK wide financial support schemes for renewable energy provides a clear incentive for harbours to become more energy efficient and pave the way in renewable energy and energy storage. It is clear from the above that harbours can become completely self sustainable both in clean energy terms and in financial terms.

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