Ports Energy and Carbon Savings

Deliverable 1.9.1

A scoping study into existing energy cooperation structures

Project No. 2S03-009

With the financial support of

Author

NAME	ORGANISATION
Parakram Pyakurel	Solent University
Anthony Gallagher	Solent University
Laurence A. Wright	Solent University

Revision history

REVISION	DATE	AUTHOR	ORGANISATION	DESCRIPTION

Table of contents

Table of figures

1. Introduction

Energy represents a significant component of an enterprises' operating costs. Even for non-energy intensive businesses, with easily affordable and accessible energy services, it represents one of the key factors effecting decisions around business development and a company's competitiveness. Initiatives that enable greater energy efficiency therefore have the potential to enhance significant business development and economic growth.

Across Europe, the growth and stability of the economies has been supported by the co-location of businesses through the development of industrial park. Such co-location and geo specific clustering offers an opportunity for a range of innovative solutions aimed at enhancing energy efficiency, which could be achieved through stimulating symbiotic relationships and facilitating energy cooperation among businesses. Such cooperation could be achieved via various routes involving building and process clustering; energy exchange; collective production; and, joint contracting of mutualised energy services.

The use of joint contracting of mutualised energy services is a promising model for industrial parks, especially when businesses are energy intensive. Today, our ability to connect and control anything from anywhere means we can manage our demand for electricity in previously unimaginable ways, and consumers are emerging as a driving force for change. By connecting everyday equipment to a smart platform, it's now possible for consumers to take advantage of small amounts of "flexible demand" in their existing assets and processes and sell it back to the electricity service provider. In the UK, for example, analysis suggests there is 6 gigawatts of peak demand which can be shifted for up to an hour without impacting end users (Open Energi). Put into context, this is equivalent to roughly 10% of peak winter demand and larger than the expected output of the planned Hinkley Point C — the UK's first new nuclear power station to be built since 1995.

Seaports are a vital part of national economies and also demonstrate high energy consumption. As with industrial parks, seaports also represent areas of industrial and business clustering, and as such, also represent locations where energy sharing can provide benefit.

The main purpose of this report is to identify energy sharing mechanisms that can be applied to small and medium sized ports, and as such it reviews the range of broad energy cooperation structures available (Section 2) and discusses them in the context of SME seaports (Section 3). Prerequisites for port energy sharing are then identified (Section 4) and the potential commodities for energy sharing are listed (Section 5). Then, energy sharing approaches for ports are developed based in findings of previous sections (Section 6). Subsequently, case studies of energy sharing mechanisms that either are established, or are in the process of being established, are presented (Section 7).

The opportunities for developing the concept of energy sharing are exciting. However, there are important barriers that could hinder such development ranging from the institutional or organisational; to financial; legal; social; and, technical. This report therefore also highlights the challenges for developing energy cooperation infrastructure (Section 8). Finally, concluding remarks are made in Section 9.

2. Current status of energy sharing

Climate change and the rapid depletion of natural resources has made energy saving and conservation a very important topic. For this reason, the EU has set itself a 20% energy savings target by 2020 (when compared to the projected use of energy in 2020 as made in 2018) – this is roughly equivalent to turning off 400 power stations (EC, 2018). Improvement of energy efficiency is one way to meet such target. The European Commission considers energy efficiency as a strategic priority, and promotes 'energy efficiency first' as a principle. It proposes to rethink energy efficiency fundamentally, and treat it as an energy source in its own right. By using energy more efficiently, energy demand can be reduced, leading to lower energy bills for consumers, lower emissions of greenhouse gases and other pollutants, reduced need for energy infrastructure, and increased energy security through a reduction of imports (Erbach, 2015).

Energy sharing mechanisms among people, companies or other infrastructure have great prospects to improve energy efficiency and also improve energy saving prospects. Given the potential of energy sharing mechanisms to reduce carbon emissions, several mechanisms that enable energy sharing have been explored. For instance, potential energy sharing models for heating and biogas businesses have been investigated by Hellstrom et al. (2015). They argue that business collaborations do not emerge like natural ecosystems, but need to be built. This collaboration building can be achieved by exploiting and connecting the interdependent elements of participating companies through various collaboration mechanisms. A case of exploiting interdependencies have been illustrated by a scenario where a boiler manufacturer could collaborate with boiler biofuel supplier by Hellstrom et al. (2015). In this case, sales of biofuel based boiler is good for both the boiler manufacturer and the biofuel supplier and this interdependency could be an enabler of potential collaboration.

Energy sharing mechanisms include peer to peer (P2P) energy transactions and energy sharing companies. P2P also includes a business to business (B2B) transaction which is basically a term used to commonly describe businesses that sell to other businesses (Andrus, A., 2018). P2P energy trading is a system where people can generate their own energy from renewable energy sources in dwellings, offices and factories, and share it with each other locally (Zhang et al, 2017). P2P markets rely on a consumer-centric and bottom-up perspective by giving the opportunity to consumers to freely choose the way to source their electric energy (Sousa et al, 2018).

P2P can provide various benefits such as creating a competitive energy market, reducing power outages, increasing overall efficiency of power systems and supplementing alternative sources of energy according to user preferences. It is expected that P2P distributed energy technology will be an integral part of the next generation power systems (Abdella et al, 2018).

Various P2P energy companies have been listed in Zhang et al. (2017) and online platforms to facilitate P2P energy sharing among "prosumers" and traditional consumers have been developed (Zhou et al, 2017). A prosumer is someone who both produces and consumes energy – a shift made possible, in part, due to the rise of new connected technologies and the steady increase of more renewable power like solar and wind onto the electric grid. A prosumer typically has renewable energy power source in his/her home for electricity production and consumption. When the electricity produced by the prosumer is not sufficient to meet the demand, the prosumer buys electricity from the grid. Likewise, when the prosumer produces more power that it can consume, he/she sells the excess power back to the grid. Figure 1 shows P2P energy sharing paradigm against the backdrop of conventional energy paradigm (Zhou et al, 2017).

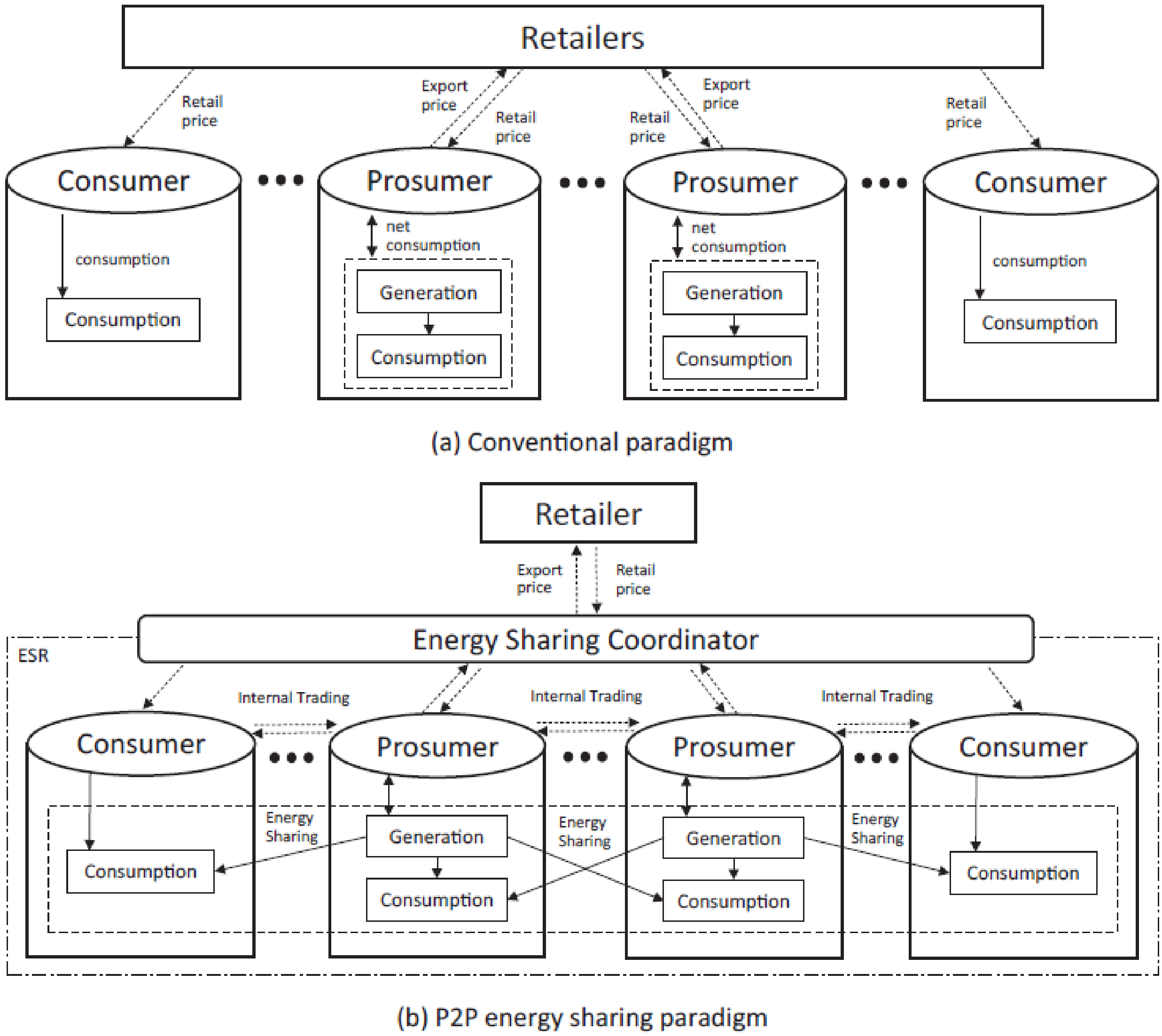

Figure 1: Conventional and P2P energy sharing paradigms (Zhou et al, 2017).

In a conventional paradigm, prosumers sell the additional electricity that they have generated back to the retailer. The retailer purchases electricity back from prosumers with an export price that is much less than the rate at which the retailer sells electricity to prosumers/consumers. In a P2P energy sharing paradigm, prosumers buy and sell electricity to energy sharing coordinator instead of the retailer. The export price of electricity that the prosumer sells to energy sharing coordinator is higher than the export price offered by conventional retailer. Therefore, P2P energy sharing mechanism is more profitable to prosumers. Traditional consumers can also benefit from the P2P energy sharing paradigm if a micro-grid infrastructure is installed by the energy sharing coordinator or any other party. In a conventional electricity grid, a consumer may only be able to purchase electricity from its contracted electricity supplier and may not be able to purchase electricity from other independent producers and prosumers. However, a micro-grid can be established in such a way that traditional consumers can buy electricity from multiple suppliers based on electricity price. This allows consumers to choose their supplier in real time and select the supplier that offers lowest electricity price.

Although there are booming research and practices in P2P energy sharing, there is still a lack of systematic methodology to evaluate and compare different P2P energy sharing mechanisms (Zhou et al, 2014). Also, several P2P energy optimization algorithms (Zhou et al, 2018; Wang et al, 2016; Long et al, 2018) have been developed for small scale communities in relationship to electricity exchange with microgrids and grids. Following requirements of P2P energy have been identified in (Murkhin et al, 2016):

- Micro-generated electricity needs to be verified, with the generation time and amount recorded. This is required, as the price of electricity varies over time based on supply and demand.
- Each unit of electricity must only ever be represented by one token on the network.

- Trades must be traceable and auditable to enable electricity suppliers (domestic and otherwise) to accurately calculate bills.

An Energy Service Company (ESCo) can be considered a P2P energy sharing mechanism. An ESCo is a commercial structure created specifically to produce, supply and manage the local delivery of decentralised energy to a "whole site" development (E.ON, 2018). An ESCo can invest capital into the energy system and assume responsibility for design and also provide operation, maintenance, billing and delivery of customer care (E.ON, 2018).

Additionally, ESCo can help protect from changes in market prices (Zhou et al, 2018). Companies like cyberGRID (cyberGRID, 2018) and E.ON (E.ON, 2018) are exploring options to share energy and may be classified as an ESCo. Likewise, European start-up "we power" (wepower, 2018) is building Blockchain-based green energy trading platform.

3. Energy sharing in the port context

Climate change has recently received more attention in the shipping sector and ports have started to introduce programmes and policies to address their carbon emissions issues (Winnes et al., 2015). Shipping emissions in ports are substantial, accounting for 18 million tonnes of CO_2 emissions, 0.4 million tonnes of NOx, 0.2 million of SOx and 0.03 million tonnes of PM10 in 2011 (Merk, 2014). Around 85% of port emissions come from containerships and tankers. Containerships have short port stays, but high emissions during these stays (Merk, 2014). However, the scope of this report is limited within port companies, industries and facilities, shipping emissions are outside the scope of this report.

The importance of minimizing carbon emissions from within port companies and facilities have also been recognized and several actions have been taken to reduce emissions from within port companies and facilities. For instance, renewable energy systems have been developed for ports (Port of Rotterdam, 2018). In the U.S., a handful of seaports are adopting bold energy-saving strategies. Two U.S. seaports are leading the charge in leveraging electrification to bolster their energy productivity and economic competitiveness. The Georgia Ports Authority's Port of Savannah is piloting four electric rubber-tyre gantry cranes, which use 95 percent less fuel than their diesel-powered counterparts by only using diesel when moving between container rows (Brickman, 2018). Likewise, the Long Beach Container Terminal at the Port of Long Beach has not only eliminated diesel-powered equipment, but it has also adopted automated cranes to increase efficiency. Since their introduction in 2016, the Long Beach Container Terminal's electrified, automated cranes and vehicles have boosted its operational efficiency (Brickman, 2018).

There are no energy sharing companies or models developed exclusively for ports but the importance of developing smart ports that utilize Internet of Things (IoT) to create a convergence between the physical and digital worlds has been highlighted (Berns et al, 2017). Similarly, energy management plans exist for ports (Boile et al, 2016; Acciaro et al, 2014) that broadly focus on sustainability and energy efficiency. Also, indicators for developing environmentally sustainable and energy efficient ports have been proposed (Vaio, 2018).

4. Prerequisites for port energy sharing

This section highlights preconditions that have to be met in order to enable energy sharing mechanisms among port companies. Firstly, it is necessary to conduct stakeholder analysis to identify potential companies that have common interests and interdependencies so that potential collaboration mechanism can be developed for these companies. Unless the participating companies have mutual benefits, it is unlikely that they would be willing to work together for energy sharing. Therefore, stakeholder analysis have to be carried out to identify potential mutual benefits that the energy sharing mechanism would enable.

Energy data sharing is very time / resource intensive and it requires energy consumption data of all port partners in resolutions of different time scales. The possibility of reducing peak demand by shifting energy use hours is only achievable when power consumption at different time instances and total energy consumption averaged over certain time periods are known. In this context, energy management platforms and smart systems are needed for automated energy data acquisition and can be considered as a prerequisite for energy sharing.

Energy platforms such as Local Energy Management (LEM) platform developed by Netherlands Organisation for Applied Scientific Research (TNO) could be an example of a tool that could fulfil energy data requirement. Likewise, Energy Potentialscan (EPS) is another platform which is also developed by TNO and can be utilized for data acquisition needed for energy sharing. Energy platforms could record and monitor energy use of all participating companies.

In addition to energy data statistics, another very important prerequisite for energy sharing is agreement and understanding among participating companies which could be in some form of written contract. In this written contract, all parties could explicitly state their commitments and expectations so that a robust cooperating mechanism can be developed.

5. Potential commodities for sharing

List of potential commodities that can be shared or recycled in an energy sharing mechanism are included here. Any process that improves energy efficiency are considered as energy sharing can take various forms. The list of potential energy and raw materials for energy sharing that could be applicable for port companies are as below:

- Electricity- electricity generation using renewable energy systems e.g. solar PV, wind, biomass etc.;
- Electricity storage units- batteries, supercapacitors, flow batteries etc;
- Heat- installation of central heating system, e.g. sharing of boilers;
- Refrigeration/cooling unit- common refrigeration unit for companies to save energy;
- Compressed air- air conditioning and other applications;
- Steam- reuse and recycling of steam for energy efficiency;
- Chemicals and chemical tanks- common chemicals such as sulfuric acid, nitrogen, ethylene etc;
- Pumps- common pump to transport liquid to participating companies;
- Material handling and transporting equipment- industrial trucks, conveyor, cranes etc.;
- Material storage unit- e.g. common warehouse to minimize space and eventually energy;

6. Energy sharing approaches for ports

Based on existing literature and the expertise within Solent University, approaches for energy sharing among facilities within a port are discussed in this section. The approaches discussed below can be applied independently or in combination with other approaches.

It is also important to develop a business plan to further consolidate the energy sharing approaches discussed here. Broadly, the business plan should consist of the following steps:

- Initial investment estimation for the energy sharing mechanism;
- Annual operation and maintenance cost estimation for the energy sharing mechanism;
- Total energy cost saving achievable from the mechanism in a year;
- Calculation of financial indicators such as payback period, net present value and internal rate of return.

Some potential energy sharing approaches are discussed below:

6.1.Sharing facilitated by an energy sharing companies

An ESCo can be established in a port which shall be a company jointly owned by facilities in the port. Facilities interested in energy sharing could invest for the establishment of an ESCo. The equity share of the facilities on the ESCo could then be proportional to their investment. The ESCo shall then install energy infrastructure based on renewable energy systems to provide energy to the port facilities that jointly own the ESCo.

6.2.Coordination among electrical appliances

Facilities within port could be operating heavy duty electrical machineries simultaneously and there could be a possibility of sequencing the operation of machineries in such a way that their operating times do not overlap. This has a potential of reducing peak electricity demand and eventually reducing the size of energy systems that power the facilities. Figures 2 and 3 show hypothetical examples where coordination between two companies, referred here as Company 1 and Company 2, can reduce total peak demand. The energy consumptions of Company 1 and Company 2 are 328 kWh and 351 kWh respectively. The power consumption patterns of these companies are shown in Figure 2.

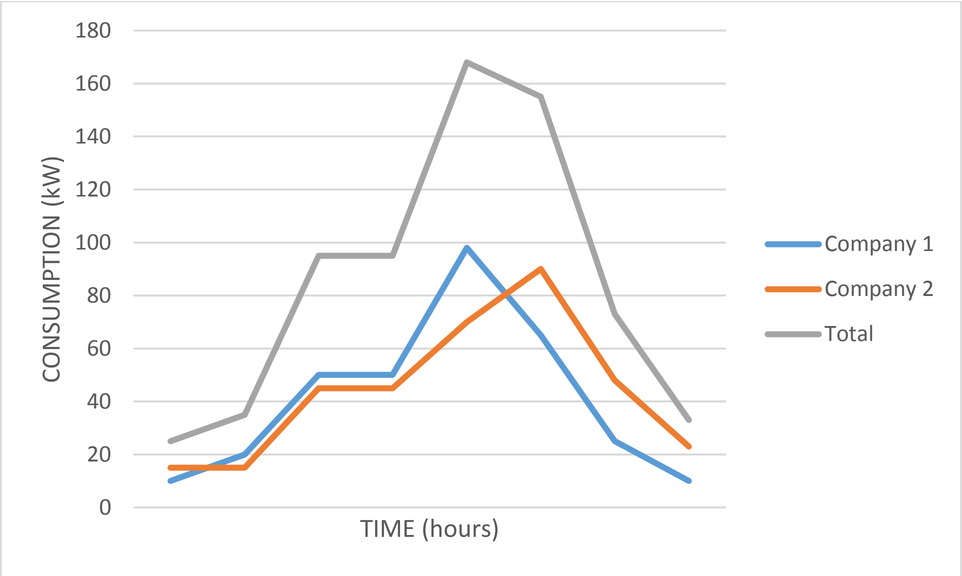

Figure 2: Example of power consumption pattern of companies before coordination

Figure 3 shows power consumption pattern of the companies after coordination between the two companies. Although both the companies are still consuming the same amount of energy, i.e. Company 1 consuming 328 kWh and Company 2 consuming 351 kWh, the maximum total instantaneous power consumption has reduced from 168 kW (Figure 2) to 145 kW (Figure 3). This is a result of both the companies smoothing out their power consumption pattern over time. Therefore, simply by adjusting their power consumptions by coordinating with one another, companies have potential to minimize the total peak power demand and eventually reduce the size of the power plant.

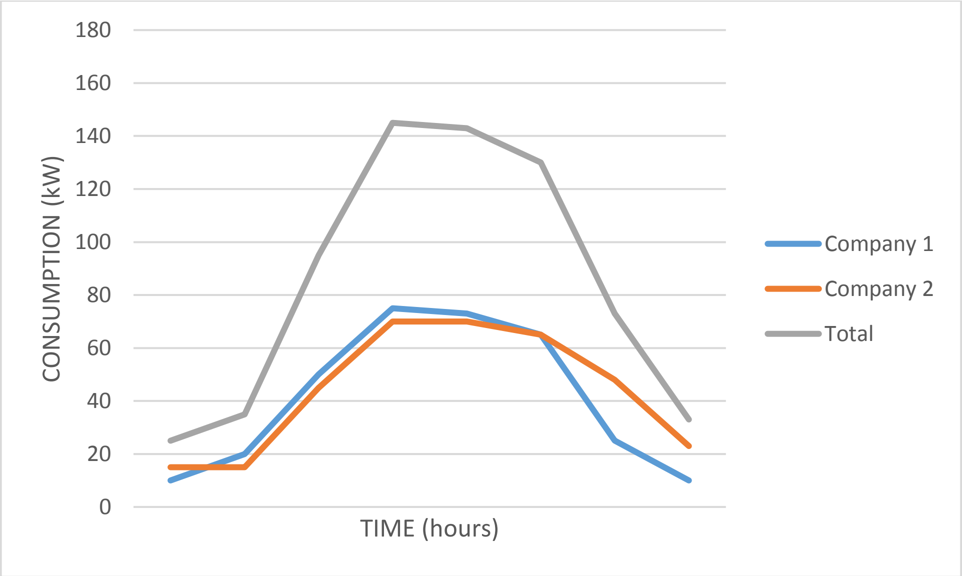

Figure 3: Example of power consumption pattern of companies after coordination

It is noteworthy that load management within a single port facility can also contribute to reduction of peak demand. Figures 4 and 5 show hypothetical examples where proper scheduling of electrical appliances in a given facility reduce peak power demand. In both the figures, the total energy consumption is same at 320 kWh. However, Figure 4 shows a case where operations of electrical appliances are sequenced in random order without any consideration for reduction of peak power demand. On the other hand, Figure 5 shows a case where operations of appliances are carried in an order that attempts to reduce peak power demand. It can be seen that when the appliances are operated in random order (Figure 4), the peak power demand is 89 kW, whereas, when the appliances are operated in a sequence intended to reduce peak power demand (Figure 5), the peak power demand is reduced to 50 kW. It is noteworthy that in both these figures, the energy consumption is constant at 320 kWh.

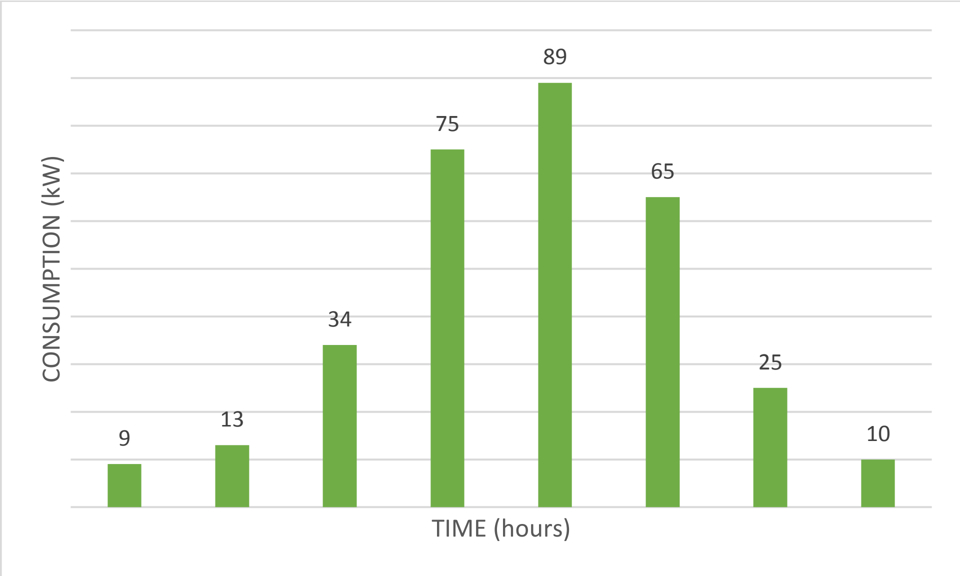

Figure 4: Example of power consumption in a company before demand side management

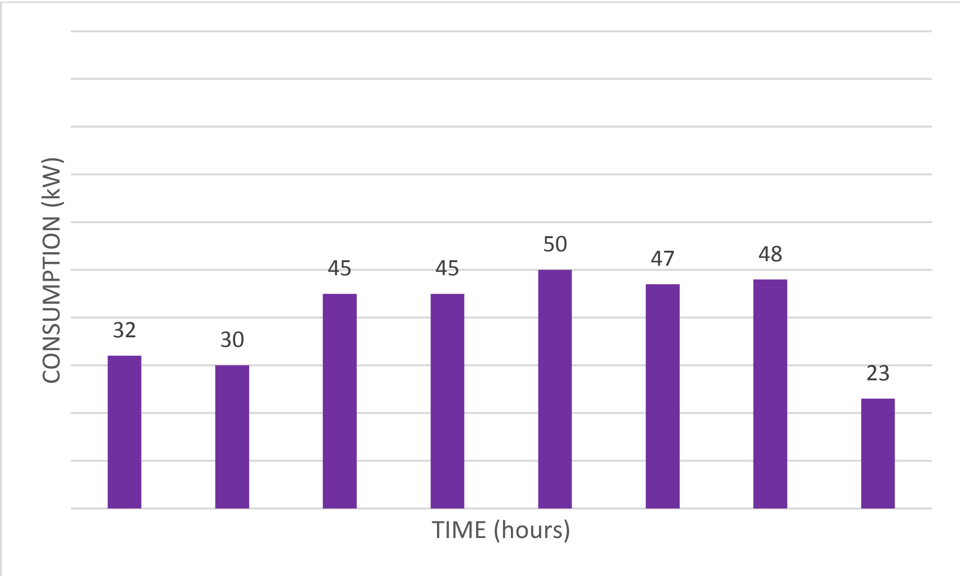

Figure 5: Example of power consumption in a company after demand side management

6.3.Recovery of waste heat and energy

There could be cases where waste heat or other forms of energy/resources produced by one facility can be utilized by another facility in the port. Energy auditing can help identify if there could be cases where waste from one facility could act as a resource to another facility. This option should be explored as it could minimize waste and improve efficiency, ultimately saving carbon emission.

6.4.Equipment/resource sharing among facilities

There could be a possibility of sharing machineries and equipment among facilities within the port and such options should be explored. If equipment can be jointly owned, this has a potential of reducing costs and also reducing the resources needed to operate the facilities within a port.

The approaches discussed above require cooperation among facilities and also detailed energy auditing. It is also unlikely that one approach will be applicable to all facilities as there could be no generic solution. Therefore, the approaches discussed here are only guidelines which can be extended into energy sharing frameworks on case by case basis.

6.5.Sharing facilitated by Internet of things

The role of internet of things (IoT) and artificial intelligence are likely to be very important in electricity demand side management in coming future and therefore, vital role of IoT in energy sharing can be envisaged. The concept is to connect high energy consuming devices by IoT such that their sequences of operations are automated by artificial intelligence-based optimization algorithms in order to minimize peak demand. Companies can set up an IoT infrastructure jointly and allow automated turning on and off equipment such that the peak demand is reduced.

6.6.Purchase of function

In this approach, companies jointly purchase functions and functional features as opposed to purchasing equipment with specific functionality. For example, a purchase of transportation of a unit weight of a material over a unit distance instead of purchasing a conveyor belt system can be a purchase of function. Schipol airport in Netherlands has adopted this principle to light its Lounge 2. Instead of purchasing luminaires, the Schipol airport is purchasing for brightness (in terms of lux) so that the luminaires can be sent back to the supplier (Philips) at the end of contract for re-use and recycle (Philips Cases, 2018). This enables circular economy and reduces the use of raw materials required to produce a specific function.

The purchase of function can allow port companies to make an optimal use of an equipment because the supplier still owns the equipment and the companies for the functional features provided by the equipment. In this way, a single equipment may be able to meet functional demand of multiple companies which can boost energy efficiency and also reduce consumption of raw materials.

6.7.Circular production approach

This approach utilizes the concept of circular economy and has been used in Kalundborg, Denmark that is known as Kalundborg Symbiosis (Kalundborg Symbiosis, 2018). This symbiosis is a partnership between nine public and private companies in Kalundborg. It is the world’s first industrial symbiosis with a circular approach to production. The main principle is, that a residue from one company becomes a resource at another, benefiting both the environment and the economy. For instance, high temperature steam from Ørsted's (one of the partners) combined heat and power plant is supplied to many of the other partners in the Symbiosis. The Symbiosis creates growth in the local area and supports the companies CSR and the climate change mitigation. Similar symbiosis potential could also exist for port companies and need to be explored.

7. Case Studies

Several case studies of energy cooperation mechanisms are presented below. All these cases are within the PECS project countries. The case studies are Waasland Port in Belgium, the port of Moerdijk in Netherlands, Ceilidh Composite Technologies in Netherlands, Voorne Putten Energie in Netherlands, Westmill Solar Cooperative in the UK and Unregulated urban property association, France.

7.1.Waasland Port

Waasland Port in Belgium has an energy sharing mechanism known as Ecluse (Ecluse official website, 2018). This mechanism is a partnership among six institutions and companies, namely, Indaver, SLECO, Infrax, FINEG, Maatschappij Linkerscheldeoever and Water-Link. In this project, steam from the Indaver and SLECO's waste-to-energy plant will be sluiced to companies in the port. The port companies can then utilize the steam. Both Indaver and SLECO are companies that provide solutions to waste management. They manufacture incinerators and other waste management equipment. This case utilizes recovery of waste heat and energy approach described in Section 5.3.

7.2.Port of Moerdijk

The port of Moerdijk in Netherlands aspires to be a front runner when it comes to sustainability and has initiated Sustainable Connections Moerdijk Programme. This port could serve as a network hub for several chemical companies (Moerdijk Port website, 2018). There exist pipeline systems in the port that connect chemical companies in Antwerp, Rotterdam, Zeeland, North Limburg and the Ruhr area. These companies could utilize the pipelines and other network infrastructure of the port of Moerdijk to use each other's raw materials and residual streams. Steam, CO_2 or hot water that are produced as waste from one company could be utilized as raw material for another company enabling an energy cooperation. This case is a mix of waste heat and energy approach (Section 5.3) and circular production approach (Section 5.7).

Another example of energy cooperation seen in Moerdijk is a power company BMC Moerdijk (BMC Moerdijk website, 2018). This company is formed as a partnership among poultry farmers (united in the form of a cooperative), energy producer PZEM Energy and ZLTO (the Southern Agriculture and Horticulture Organization). Poultry manure that is produced as waste from poultry farming is used as a fuel for electricity generation by BMC Moerdijk. The poultry manure is incinerated, and the steam generated from the incineration is used to produce electricity. In addition to electricity, high quality fertilizers are also produced as the remains of the incineration process.

7.3.Ceilidh Composite Technologies

Ceilidh Composite Technologies is a Netherlands based company that specializes in manufacturing carbon fibre parts for a wide range of applications (Ceilidh Composite Technologies website, 2018). This company has its roof covered with 152 solar PV panels and thus generates its own electricity. Since the company is located very close to a port in Hellevoetsluis. The electricity it generates is divided between Ceilidh and the port. Two thirds of the electricity is used by Ceilidh and the remaining third is used by the port and office. This case utilizes resource sharing among facilities approach described in Section 5.4.

7.4.Voorne Putten Energie

Voorne Putten Energie (VPE) is an energy cooperative in Netherlands develops sustainable energy projects in the Voorne Putten Island (VPE website, 2018). The municipalities and the Government of the Netherlands have aimed to power the Voorne-Putten Island solely by sustainable energy by 2050 and to achieve this goal, VPE was established in 2017. This company runs a project called "solar panels on someone else's roof". There are residents in Voorne Putten Island who wish to install solar panels. However, they either do not own a roof (apartment owning/renting residents) or due to planning requirements cannot install solar panels on their roof. This project allows them to fund solar panel installation on other vacant roofs. The financial benefit these residents get from facilitating the installation of panels on other's roofs are energy tax benefits and they may also be able to claim electricity charge. Since both the owner of a roof and a resident without roof who is willing to install panel on someone else's roof may not have expertise to install panels, VPE does all the panel design and installation work. Thus, VPE acts as a coordinator that enables energy cooperation between a resident with an empty roof and a resident without a roof but who is willing to install panels. This case is a mix of "sharing facilitated by an energy sharing companies" approach (Section 5.1) and the "purchase of function" approach (Section 5.6).

The VPE approach can also be feasible for apartment building complexes where there are residents that own individual apartment units. As a hypothetical example, an apartment building complex with 3 floors and 8 individual apartment units can be considered. This would give 24 residents/families and only 1 roof. If the roof of the building can accommodate, say, 72 panels, then each apartment unit owner could purchase for 3 panels (24 residents purchasing 3 panels each gives a total of 72 panels).

7.5. Westmill Solar cooperative

Westmill Solar cooperative is the largest solar cooperative in the UK with around 1500 members (ethex, 2018). It has an installation of 4.8 MW solar park on the Oxfordshire/Wiltshire border. The plant covers 30 acres and generates enough electricity to power 1,600 homes. This is a grid connected project which has power purchase agreement with Co-op Energy. Westmill Solar Co-operative is financed by £5.8 million in equity from more than 1,500 members and a 20-year loan of £12 million from Lancashire County Council Pension Fund. The Co-operative receives income from the sale of electricity to Co-op Energy and from Government subsidies under the Feed-In Tariff scheme and other small schemes. The cooperative contracts the management of solar plants to RINA which is an experienced independent engineering consultancy specialising in technical advisory work for the renewable energy market. Likewise, management of the Co-operative itself is contracted out to Ethex which is a small not for profit organisation based in Oxford UK with the aim of creating a marketplace for positive investments.

The project benefits members of Westmill Solar cooperative, the local community and the environment. Members receive an annual return providing an indirect benefit to the local economy. Furthermore, members can also take credit of carbon-free electricity. As this is a community owned project, Westmill Solar members have established a Community Fund to support clean, green renewable energy locally and around the world. Additionally, they financially supports Westmill Sustainable Energy Trust (WESET), a local charity promoting education about sustainable energy.

7.6. Unregulated Urban Property Association

An Unregulated Urban Property Association (AFUL) is an informal organization of land and property owners that exists in France. One AFUL in Chantrerie, Nantes known as AFUL Chantrerie practices energy cooperation. AFUL Chantrerie was established in 2010 and is composed of five organizations that include three engineering schools, one university and the Loire –Atlantique department (local government unit). This AFUL has constructed a biomass plant of 2.5 MW for district heating which has reduced the heating cost of participating organizations by 5%. Additionally, AFUL Chantrerie has also installed 70m² of PV on the roof of the wood storage room of the biomass plant.

In addition to AFUL Chantrerie, other energy cooperation cases also exist in France. For example, IndaChlor, a waste management company and also a PECS partner, is providing effluent steam to another brewery company. Likewise, institutions known as Cooperative Society of Collective Interest (SCIC) are also found in France. An SCIC is a multi-stakeholders company with social dimension that integrates local communities, businesses and volunteers.

8. Challenges

There are several challenges associated with enabling energy sharing among companies in a port. One major challenge is the willingness of companies to cooperate on energy sharing mechanisms. Energy sharing also requires sharing of energy consumption data among participating companies and companies might not be willing to share their energy use data with others. Furthermore, the exact energy consumption data might not be available and energy sharing mechanism requires energy use data.

Another major challenge is securing the investment required for energy cooperation. All of the energy sharing approaches discussed above (Section 5) require investment for setting up physical infrastructure and/or software. Renewable energy systems such as solar PV or wind turbines may have to be built and software for energy data acquisition and sharing may also have to be installed. These require initial investment and monthly operational and maintenance cost also may be involved. Therefore, business plans have to be made for energy sharing mechanisms in a case by case basis.

Companies also might feel that energy sharing structures reduce their autonomy over energy systems which will reduce their willingness to participate in energy sharing. For example, an energy plant that is shared by two or more companies in joint ownership mean that no single company has full control over the power plant. The lack of full control over power plants might discourage companies to opt for energy sharing.

9. Conclusions

The scope for implementing some form of energy cooperation amongst businesses, so as to reduce energy consumption, and make businesses more energy efficient, is starting to receive considerable attention both across Europe and beyond. As an approach, it offers considerable opportunity for enhancing economic growth as well progressing the move to a lower carbon future.

This review has identified examples of how and where such initiatives are developing as well as outlining some of the prerequisites and possible options for such development. This will now inform the development of a specific but flexible methodological approach to be employed and tested within the framework of the Port Energy and Carbon Savings project.

10. References

Abdella, J., Shuaib, K. (2018) "Peer to Peer Distributed Energy Trading in Smart Grids: A Survey," *Energies*, 11(6), Available at: https://doi.org/10.3390/en11061560.

Acciaro, M., Ghiara, H., Cusano, M. I. (2014) "Energy management in seaports: A new role for port authorities," *Energy Policy*, Vol. 71, pp. 4-12.

Andrus, A. (2018) "Business-to-Business: Breaking Down the B2B Business Model," *Disruptive Advertising*, Available at: https://www.disruptiveadvertising.com/business/business-to-business/.

Berns, S., Dickson, R., Vonck, I., Dragt, J. (2017) "Smart Ports: Point of view," Deloitte, Available at: https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/energy-resources/deloitte-nl-er-port-services-smart-ports.pdf.

BMC Moerdijk. (2018). Available at: https://www.bmcmoerdijk.nl/nl/over-bmc.htm.

Boile, M., Theofanis, S., Sdoukopoulos, E., Plytas, N. (2016) "Developing a Port Energy Management Plan Issues, Challenges, and Prospects," Transportation Research Record: Journal of the Transportation Research Board.

Brickman, S. (2018) "Seaports Need A Lot Of Energy, But Electrification Can Reduce Pollution And Costs," *Alliance to save energy*, Available at: https://www.ase.org/blog/seaports-need-lot-energy-electrification-can-reduce-pollution-and-costs.

Ceilidh Composite Technologies. (2018). Available at: http://www.carbonmasts.com/.

cyberGRID. (2018). Available at: https://www.cyber-grid.com/about-cybergrid/.

Energy Market Authority. (2018). Available at: https://www.ema.gov.sg/Demand_Side_Management.aspx, Singapore Government.

Ecluse official website. (2018). Available at: http://www.ecluse.be/homepage/.

E.ON UK plc. (2018). Available at: https://www.eonenergy.com/for-your-business/community-energy/esco-solutions.

E.ON UK plc. (2018). Available at: https://www.eonenergy.com/for-your-business/gas-electricity.

E.ON UK plc. (2018). Available at: https://www.eonenergy.com/About-eon/our-company/at-a-glance.

Erbach, G. (2015) "Understanding energy efficiency" *European Parliamentary Research Service, Briefing- October 2015*, Available at: http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568361/EPRS_BRI(2015)568361_EN.pdf

ethex (2018) "Westmill Solar", Available at: https://www.ethex.org.uk/Westmillsolar.

European Commissions (EC). (2018). Available at: https://ec.europa.eu/energy/en/topics/energy-efficiency

Hellstrom, M., Tsvetkova, A., Gustafsson, M., Wikstrom, K. (2015) "Collaboration mechanisms for business models in distributed energy ecosystems," *Journal of Cleaner Production*, Vol. 102, pp. 226- 236.

Kanundborg Symbiosis. (2018). Available at: http://www.symbiosis.dk/en/.

Long, C., Wu, J., Zhou, Y., Jenkins, N. (2018) "Peer-to-peer energy sharing through a two-stage aggregated battery control in a community Microgrid," *Applied Energy*, Vol. 226, pp. 261-276.

MoerdijkPort website. (2018). https://www.portofmoerdijk.nl/en/usrs/sustainable-hub-for-chemicals/.

Merk, O. (2014) "Shipping Emissions in Ports" International Transportation Forum, OECD, Available at: https://www.itf-oecd.org/sites/default/files/docs/dp201420.pdf.

Murkin, J., Chitchyan, R., Byrne, A. (2016) "Enabling peer-to-peer electricity trading," *4th International Conference on ICT for Sustainability* (ICT4S 2016).

Philips Cases. (2018) "Circular lighting at Schipol airport," Available at: http://www.lighting.philips.com/main/cases/cases/airports/schiphol-airport.

Port of Rotterdam (2018) Available at: https://www.portofrotterdam.com/en/doing-business/setting-up/existing-industry/energy-industry/sustainable-energy.

Sousa, T., Soares, T., Pinson, P., Moret, F., Baroche, T., Sorin, E. (2018) "Peer-to-peer and community-based markets: A comprehensive review," Available at: http://pierrepinson.com/docs/Sousaetal2018.pdf.

Vaio, A. D., Varriale, L., Alvino, F. (2018) "Key performance indicators for developing environmentally sustainable and energy efficient ports: Evidence from Italy," *Energy Policy*, Vol. 122, pp.229-240.

VPE website. (2018). Available at: https://www.voorneputtenenergie.nl/.

Wang, H., Huang, J. (2016) "Incentivizing Energy Trading for Interconnected Microgrids," Available at: https://arxiv.org/pdf/1609.07576.pdf.

wepower. (2018). Available at: https://wepower.network/.

Winnes, H., Styhre, L., Fridell, E. (2015) "Reducing GHG emissions from ships in port areas," *Research in Transportation Business & Management*, Vol. 17, pp. 73-82.

Zhang, C., Wu, J., Long, C., Cheng, M. (2017) "Review of Existing Peer-to-Peer Energy Trading Projects," *Energy Procedia* 105 (2017) 2563-2568.

Zhou, Y., Wu, J., Long, C., Cheng, M., Zhang, C. (2017) "Performance Evaluation of Peer-to-Peer Energy Sharing Models," *Energy Procedia* 143 (2017) 817-822.

Zhou, Y., et al. (2018) "Distributed Energy Management of P2P Energy Sharing in Energy Internet Based on Cloud Energy Storage," *e-Energy '18*, June 12–15, 2018, Karlsruhe, Germany, Available at: https://doi.org/10.1145/3208903.3208906.

Zhou, Y., Wu, J., Long, C. (2018) "Evaluation of peer-to-peer energy sharing mechanisms based on a multiagent simulation framework," *Applied Energy*, https://doi.org/10.1016/j.apenergy.2018.02.089.