WP 3.5
Application of Smart Energy Networks – part I
Summary results of the individual company demand response audits in the Port of Antwerp

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Photo: Colourbox

Contents

1 Introduction

Smart energy networks are intelligent and flexible solutions which combine flexible energy consumption, local generation of (renewable) energy and energy storage on different levels. In any smart energy network, the presence of flexible energy consumption is crucial. This document summarizes the results of a search for the presence of demand side flexibility in the Port of Antwerp. Five companies participated in this project i.e. Amoras, Borealis, Luiknatie, Norbert Dentressangle and SEA-invest.

This chapter explains the "way of working" and scope of the document. Chapter 2 gives a summary of the response audits for each individual company. Chapter 3 contains some new harbour specific sources of flexibility and Chapter 4 contains the conclusions.

1.1 Universal business cases

The final document of WP3.4, "Strategies and Business Cases for Smart Energy Networks " [1], gives an overview of universal business cases for the exploitation of smart energy networks. Demand side flexibility is a term which is used for devices, installations and/or companies which are able to adapt the energy consumption to some extent without compromising their proper operation. Examples are installations which can shift non critical activities in the time or devices which can store energy for later use. The economical potential of the flexibility, offered by these devices, installations and/or companies is estimated in the WP3.4. WP3.4 summarizes the following cases:

- Contract optimization: The present flexibility can be used in order to reduce the energy cost within the margins of the existing energy contract. Examples are shifting energy consumption to cheaper off-peak tariff hours or reduction of the peak power.
- Trade on the wholesale market: Significant amounts of energy are traded on energy exchange markets. Due to the variable price on these energy markets, the presence of flexibility can be used for energy cost reduction.
- Balancing group settlement: Balancing responsible parties (BRP's) are responsible for balancing electricity production and consumption in their portfolio. Flexible consumers can help a BRP in order to maintain the balance of his portfolio.
- Offer reserve capacity: In case BRP's are not able to maintain the system balance, the transmission system operator (TSO) has reserve capacity in order to restore the balance. Customers can offer their flexibility directly to the TSO for balancing purposes of the total system control area.
- Local system management: The local distribution grid has a limited capacity and some combinations of local power injection and consumption may result in congestion. Flexibility can be used to operate the local grid in an optimal way within its constraints.
- Offer further grid stabilization services: Large scale producers and consumers can offer flexibility for reactive power balancing or preventing congestion of the transmission grid.

The scope of WP3.5 is the translation of the "theoretical" business cases of WP3.4 into realistic business cases in a harbour context. In order to get results as realistic as possible, it was decided to work with actual energy consumption data of companies in the Port of Antwerp. In co-operation with the Antwerp Port Authority, a list of companies with a "good potential" for flexibility was made. The companies on that list were contacted and 5 were willing to cooperate in a detailed flexibility analysis.

The conclusions of the investigations in WP3.5 are summarized in 2 documents:

- **WP 3.5 - Application of Smart Energy Networks – part I: Summary results of the individual company demand response audits in the Port of Antwerp** (this document): In this document the flexibility of each individual company is quantified and the value of local optimization is estimated.
- **WP 3.5 - Application of Smart Energy Networks – part II: Cluster analysis of the combined company flexibility in the Port of Antwerp**: In this document the flexibility of all screened companies is combined into a Virtual Power Plant (VPP) [2].

1.2 Demand response audit: A general way of working

In a demand response audit, the flexibility of a device, installation or company is explored. A full demand response audit consists of the following steps: Identification, quantification, valorisation and exploitation.

Identification of flexibility

In a first step the presence of flexibility in an installation or company is screened. Flexibility requires a combination of specific properties of the installation. Typically a combination of "direct" or "indirect" storage (energy or products) and a certain amount of overcapacity of the installation results in flexibility. Flexibility is a quite new concept and is not easily recognized in standard energy audits. For that reason a detailed technical screening of the installations is required in close cooperation with the technical people of the company.

Quantification of the flexibility

Flexibility contains aspects of "time", "energy","power" and "frequency" which are related. During the quantification step the technical properties of the installation are translated into values which are independent of the type of installation.

Valorisation of the flexibility

As explained in [1], flexibility can be used in several ways in order to come to a valid business case. Depending on the type of flexibility, the specific properties of the installation and the wishes of the company a number of business cases are selected and calculated. This allows the selection of the business case where the present flexibility results in the highest added value.

Exploitation of the flexibility

Depending on the valorisation scenario and the specific properties of the installation, the complexity of a system for the exploitation of the flexibility may differ. In some cases simple manual settings changes are sufficient, in other cases complex self learning algorithms may be needed in order to achieve optimal results. In many cases, however, relatively simple solutions are sufficient in order to exploit 80% of the flexibility where very technical complex solutions are needed in order to exploit the last 15-20%.

1.3 Scope of the e-harbours demand response audits

All companies, which were prepared to co-operate in a demand response audit for the e-harbours project, were screened in several steps:

1. Initial visit to the company for aligning expectations and a first rough estimation of the potential. During the initial visit, arrangements are made for receiving a power consumption profile and the current energy contract.
2. Second visit for a detailed technical screening of the installations.
3. Analysis of power consumption profile and the energy contract.
4. Quantification of the available flexibility based on e a simplified model of the technical installation.
5. Calculation of the value of the flexibility for several business cases.
6. Third visit of the company for presenting the results of the demand response audit in a presentation and an “Intermediate report”

In the approach, step 4 and 5 are only performed in case there are indications for a significant potential of flexibility in the installations. In this report, the focus is on the application of the flexibility within the company itself. For that reason the following business were selected:

- *Energy cost reduction by using the present flexibility within the margins of the existing energy contract*: this typically results in optimal shifting of energy consumption to off-peak tariff and peak load reduction
- *Energy cost reduction by trading on the wholesale market*: In principle, the wholesale energy markets are only accessible for huge energy consumers. Smaller consumers can buy energy on the wholesale markets via intermediate companies who bundle the requests of many small companies.

The e-harbours demand response audits are focused on the “potential” business cases and not on an actual implementation. For that reason, the way how the flexibility can be exploited , is not within the scope of this report.

Every company received an extensive “intermediate report” with all simulation results. These reports are “confidential” and not part of the e-harbours deliverables. These documents contain simulation results which are based on financial and energy consumption details which might be of strategic importance.

1.4 Extended scope

The Antwerp Port Authority is currently investing in a big wind farm in the Port of Antwerp. Many Antwerp harbor companies will get the opportunity to have one of the wind turbines on their company estate. They will have the possibility to buy electrical energy "directly" from the wind turbine without the intermediation of the Distribution System Operator (DSO). In principle this is financially interesting because:

- no distribution and transmission fees have to be paid on the wind energy
- the value of wind energy is lower, and thus cheaper for the companies, due to its intermittent character.

This results in an electrical energy price which is 40% to 50% lower than the electricity tariffs applicable when buying electrical energy from a traditional supplier. However, the company itself is responsible to sell its excess wind energy to an energy supplier or energy market(s) when applicable.

At the time, the e-harbours assessments took place in the Antwerp harbour, most visited companies were considering the opportunity of a wind turbine, but were struggling with the question: "What will be the (positive) impact on my energy bill in case the available energy is used in a smart way?".

Given this context, the economical potential of integrating a wind turbine on company level is considered a useful extension to the original scope. For 4 companies the calculation has been performed.

2 Individual company screening: summary results

2.1 SEA Invest

2.1.1 Introduction

SEA-invest is one of the world's largest terminal operators for dry bulk, fruit and liquid bulk and is active in 25 ports worldwide. SEA-invest has multiple activities in the Port of Antwerp. For the e-harbours project the discussions have taken place with the SEA-invest Fruit and Food Division. SEA-invest Fruit and Food Division mainly focuses in Antwerp on storage and riping of exotic fruits (e.g. bananas, pineapples, etc.).

SEA-invest Fruit and Food Division has cold stores of all sizes, all focusing on cooling (-1°C …+14°C range). Generally, cold stores are known for their flexibility but typically temperature margins are wider in cold stores for freezing compared to cooling.

2.1.2 Investigation summary.

Available information

For the investigations at SEA-invest, the following information was available:

- Detailed description of the installations
- No energy contracts of neither locations in the harbour
- Power consumption profiles of the 8 different distribution grid connection points of SEA-invest.

Power consumption analysis

In a first screening, the power consumption profiles of the 8 connection points (locations) were investigated. All locations show a typical day/night pattern with higher consumption during the day time and a lower consumption during the night and the weekend. There are no indications that there is an "active" use of the lower energy prices during the night or the weekend. The power consumption during the night is typically 20 to 30% lower than during the day. Over the year the power consumption shows a typical seasonal variation: power consumption is 20-25 % lower in the winter compared to the summer. This behaviour is typical for cold stores while general power consumption is higher during the winter compared to the summer

The 8 locations can be mainly organized into 3 groups: storage facilities used as backup solution, manual operated terminal, and automated terminals.

- <u>Manual operated terminal</u>: In the manual operated terminal, the power consumption is 30 to 40% lower during the night compared to the day. During the weekend the power consumption drops even with 50-60% compared to the typical day consumption. Every week day, the power consumption is maximum between 18:00h and 21:00h, most probably because forklifts are connected for charging. Quite remarkable is the increase of the average power consumption from Monday to Wednesday, on Thursday and Friday the power consumption decreases again.

- Automated terminals: In the automated terminals, the power consumption is also lower during the night compared to the day, but the difference is limited to 10-15%. Also the differences between the weekend and weekdays are smaller.

Quantification of the flexibility

The results of the power consumption analysis were discussed with SEA-invest in order to identify the presence of flexibility. Several options for flexible consumption and production were addressed:

- Temperature margins: In a cold store, more flexibility can be achieved in case wider temperature margins can be used. SEA-invest clearly indicated that accurate temperature control is an important part of the quality of the storage and riping process of fruits. For that reason, enlarging temperature margins is not an option.
- Forklift charging: The power consumption analysis shows that fork lift charging represents a significant part of the power consumption of a manually operated terminal. Charging starts typically in the late afternoon. In the discussions it was suggested to postpone the charging till the cheaper night energy tariff. According to SEA-invest, charging the forklifts should happen as soon as possible in order to be ready for early arrival of new cargo.
- Harbour cranes: SEA-invest has several diesel harbour cranes. The actual motors which operate the crane are electric. The diesel engine drives an electric generator in order to supply the electricity to the motors. The harbour cranes are in use for 25-50% of the time. In case the harbour crane could be connected to the grid, they could function as backup diesel generators.
- Reefers: SEA-invest has connection points for refrigerated containers (reefers). Reefers have a typical on/off power consumption profile. The typical power consumption when switched "on" is 10-15kW, the average power consumption of a reefer is 3-4kW. Sometimes the number of reefers connected is very high and additional diesel generators are needed to provide the electrical power.

2.1.3 Conclusions

The discussions and investigations at SEA-invest Fruit and Food Division did not result in a concrete quantification of flexibility. SEA-invest already pays a lot of attention to the reduction of energy consumption. The constraints set by the company are so tight that insufficient flexibility is available to create a valid business case. This conclusion was confirmed by another external energy audit (BECO). For that reason, the remaining flexibility was considered too low and didn't justify further analysis.

Nevertheless, the discussions with SEA-invest resulted in an important conclusion: *"The exploitation of flexibility should not influence security, quality or continuity of the company's main activities."* This conclusion is nicely illustrated within SEA-invest with the following 2 examples:

- Temperature limits in cold stores for exotic fruits are very tight and are integral part of the quality control process. Wider temperature limits introduce flexibility, but may harm the quality of the company's core activities which is unacceptable.
- Charging forklifts has a high priority in order to be ready for unloading the next vessel which arrives. Charging during the "off peak" hours results in a cost reduction, but may harm the continuity of the company's core activities which is unacceptable.

Further, the discussion with SEA-invest resulted in 2 new ideas for finding flexibility: reefers and harbour cranes. These topics will be discussed in a separate section of this document.

2.2 Amoras

2.2.1 Introduction

The Port of Antwerp is located about 70 km from the North Sea on the river Scheldt. In order to keep the Port of Antwerp competitive, continuous dredging of the river and in the docks is needed, in order to give ships with more draught access to the Port of Antwerp. In the docks on the right bank, this results every year in more than 1.000.000 m³ (± 500.000 tons dry matter) of dredged material which has to be processed. AMORAS is the name of a facility which was recently built as a sustainable solution for the dewatering of sludge.

AMORAS has 2 different locations in the Port of Antwerp: quay 536 in the docks and the 'Bietenveld'. At quay 536 the sludge is accepted in a first buffer: the underwater cell. The sludge is dredged again with an electric cutter and on land a coarse sieving and desanding takes place before the sludge is pumped to the second location. At the 'Bietenveld', the sludge arrives in a second big buffer: the thickening pools. From the second buffer the sludge is pumped in to the mechanical dewatering installations for final processing and storage. (Dutch/English website: http://www.amoras.be/)

2.2.2 Investigation summary

Available information
For the investigations at AMORAS, the following information was available:

- Detailed proces information
- Energy contracts of both locations in the harbour
- No power consumption profiles

Quantification of the flexibility
In a first technical screening, it was immediately clear that the AMORAS facility has a huge potential for the exploitation of flexibility. Both locations have huge buffers, which can store sludge for days up until weeks. The pump installation, which is responsible for the transport of the sludge from the first location to the second, has a capacity which is significantly higher than the capacity of the mechanical dewatering installation. The combination of large buffers and overcapacity are perfect ingredients for the presence of flexibility and a simplified model of the Amoras installations was made for further simulations.
In the simulations, 2 scenarios were compared:

- Scenario 1: the AMORAS installations are operated in the same way as they are operated nowadays, but in combination with a wind turbine.
- Scenario 2: the flexibility within the Amoras installations is used in such a way that a maximum of wind energy is used.

Due to the large buffers and due to the large overcapacity of the pump installation, simulations showed that it is possible to operate the pump installation completely on wind energy. Without optimization, 60% of the produced wind energy can be used in locally. In case the flexibility is used in an optimal way, almost 80% of the wind energy can be used locally. This results in an overall energy cost reduction of almost 20%.

2.2.3 Conclusions

The flexibility of the Amoras facilities is extraordinary big compared to the other companies screened in the Port of Antwerp. This is caused by a combination of huge buffers and overcapacity of the pump installations. Due to the fact that the buffers can store sludge over a timescale of days to even weeks, the Amoras facility is extremely well suited for local wind balancing.
During the feedback discussions with Amoras the following concerns for the actual exploitation of the flexibility were raised:

- The pumping installations cannot be operated without staff: currently, the pumping installations are operated only during the traditional office hours.
- The operation of the Amoras installations requires the availability of staff. Although the amount of staff needed is limited, full exploitation of the present flexibility requires staff during the night and weekend. This has a significant social impact on the working conditions of the staff.
- The daily operation of the Amoras facilities is outsourced to an external company who is responsible for e.g. staff. The costs of energy consumption, however, is not the primary responsibility and concern of the external company. They have to deal with the operational/practical consequences i.e. costs of the exploitation of flexibility, but are not financially rewarded under present contract. This is a matter of negotiations and new agreements with the principal, but should not be an additional “hurdle” to the exploitation of flexibility.

2.3 Borealis

2.3.1 Introduction

Borealis is a world player in the production of chemicals and innovative plastics. The Borealis facility in the Port of Antwerp produces polypropylene pellets. The production process consists of 3 major steps: a dehydrogenation process for the conversion of propane to propylene, a polymerization process for the conversion of propylene into polypropylene powder and an extruder section for the conversion of polypropylene powder into pellets. The electrical energy consumption is sizeable and characterized by a very constant demand. Borealis has a direct connection to the high voltage network of Elia, the Belgian transmission system operator. For the e-harbours project, it is very interesting to have a company as Borealis in its portfolio because it represents a typical “process industry” facility, known for its large energy consumption and very constant energy demand. Consequently, it is expected that not much flexibility can be found in this type of plants. The Borealis case allows to validate this assumption.

2.3.2 Investigation summary

Available information
For the investigations at Borealis, the following information was available:

- Full year power consumption profile
- Top level proces information
- No details on the energy contract.

Power consumption analysis
In a first phase, the power consumption profile of Borealis was investigated based on quarter hourly measurement data which confirms the extreme constant power consumption. Nearly no daily day/night pattern nor seasonal patterns are visible. The typical power variations are just a few percent of the total power consumption. In the technical discussions with Borealis, however, flexibility was identified and it was decided to make a simplified model of the Borealis production process.

Quantification of the flexibility
With the model it was shown that power consumption can be controlled within +4% and -6% for a significant amount of time, without major consequences for the production process. In this case the flexibility is “lossless”: this means that using the flexibility does not result in extra energy consumption. Reductions up to 16% are theoretically possible, but the impact on the production process is significantly higher and the usage of the flexibility is not “lossless”: this means that using the flexibility results in extra operational costs.

With the model several case studies/scenarios were calculated:

- <u>Standard energy contract</u>: Under the assumption that Borealis has a standard energy contract (contract details were not provided), it was shown that the available flexibility might reduce the energy consumption costs with 0.5%.
- <u>Local wind energy optimization</u>: In this case the optimal usage of locally installed wind power was analyzed. The power consumption of Borealis is so large that locally generated

renewable energy can always be used locally, and that flexibility is not needed in order to improve local power usage.

- Belpex energy optimization: In this case it was assumed that all energy was bought on the Belgian day ahead power exchange. Optimal use of the flexibility results in a reduction of the energy consumption costs of 1%.

2.3.3 Conclusions

A search for flexibility in a company like Borealis shows that it is possible to find flexibility in the process industry although they strive to a high level of continuity in their processes.

Based on the extremely constant power consumption profile, it was expected that the flexibility within Borealis was limited. However, the present flexibility is significantly higher than expected.

At this moment, there is no business case: As the case studies show, the flexibility can be used to reduce the energy costs, but the gains are limited compared to the total energy consumption of the entire plant. During the feedback discussion with Borealis, it was clearly indicated that the current financial profit is not substantial enough to consider the actual exploitation of the flexibility as that would inevitably require organizational and/or technical adaptations.

Furthermore, it was indicated that the continuous and predictable power consumption is often a benefit in commercial energy sourcing contract discussions. This indicates that local exploitation of the flexibility within the company might result in a worse position for price negotiations, which increases the reluctance to make steps in the direction of actively using the flexibility. For that reason it seems to be a better idea to exploit the present flexibility in cooperation with the energy supplier and/or the transmission grid operator.

Companies, like Borealis, might get very competitive conditions from energy suppliers due to their high level of “predictability”. From the point of view of the supplier, the company loses some “predictability” in case the flexibility is exploited locally which might result in worse rates. In case the company exploits the flexibility in cooperation with the energy supplier, the energy supplier gets a certain level of “controllability” on the power consumption which is even more valuable than “predictability”. Energy suppliers typically have a balancing responsibility and the flexibility of their customers can help to maintain the balance. For that reason it is reasonable to assume that customers get better rates in case they are helping the supplier in their balancing responsibilities.

2.4 Norbert Dentressangle

2.4.1 Introduction

Norbert Dentressangle is an international company with a base in Antwerp from where they offer customers a broad range of handling and logistic services to maritime related cargo flows moving through the port of Antwerp. Norbert Dentressangle can provide activities as freight management and transport, warehousing and distribution, terminal operations, short sea and deep sea shipping, stuffing and stripping of containers and all related administration. One of the divisions is the Fresh division, focusing on storage and distribution of temperature controlled perishable products. A new 162.000m3 temperature controlled storage facility was built in 2008 split up in 5 storage cells for cooling and 4 for deep-frozen products. The flexibility, present in this cold store facility was investigated during the e-harbours project.

2.4.2 Investigation summary

Available information
For the investigations at the Fresh cold store, the following information was available:

- Detailed information of the refrigeration system, including log data
- Detailed information about the insulation of the building
- Energy contracts
- Full year power consumption profile

Power consumption analysis
The power consumption data shows some variation in the energy consumption from month to month, but not as much as expected. This is probably due to the high insulation level of the building and a significant activity in cooling where the goods flows are higher and the cooling capacity depends more on the temperature of the incoming goods.

The analysis shows as well that there is nearly no activity during the weekends and the energy consumption is typically double as high during the day compared to the nights. Norbert Dentressangle has a standard energy contract with higher energy prices during the day compared to the night and weekend. Nevertheless, the power consumption data shows that Norbert Dentressangle does not use this price difference actively to reduce the energy consumption bill.

Quantification of the flexibility
Cold stores are well known the presence of flexibility, but the quantification is not easy. The present flexibility heavily depends on the insulation level of the building, the total thermal capacity of the stored goods, the activity in the building, the temperature of the goods arriving and their storage time. The presence of detailed log data helped to develop a relatively simple approach in order to achieve a simplified cold store model from the power consumption data. This cold store model was used for further simulations.

In the simulations, 4 scenarios were compared:

- <u>Scenario 1</u>: Simulations with a standard contract and without wind turbine.
- <u>Scenario 2</u>: Simulations with a standard contract and with wind turbine.
- <u>Scenario 3</u>: Simulations with Belpex prices and without wind turbine.
- <u>Scenario 4</u>: Simulations with Belpex prices and with wind turbine.

For each scenario, 4 simulations were performed: a reference simulation with a constant temperature of -20°C in the cells, a simulation with a temperature between -20°C and -22°C, a simulation with a temperature between -20°C and -25°C and a simulation where the temperature must be lower than -20°C.

The simulations with a standard contract show a theoretical yearly cost reduction of 9%. The cost reduction is calculated as the difference between the total yearly cost of the reference simulation and the simulation where the temperature must be lower than -20°C. In practice, most of the cost reduction can be achieved with a temperature window of 5°C.

In combination with wind energy, the results are even better: by means of intelligent control, the amount of energy bought in day tariff can be reduced with 60 to 70%, also in night tariff the reduction goes up to 40%. This results in a global yearly cost reduction of 15%. It is important to note that also here, the cost reduction is calculated as the difference between the total yearly cost of the reference simulation and the <-20°C simulation both with the presence of a wind turbine. The 15% is purely realized by the optimization. In all simulations, a big part of the cost reduction is achieved due to a reduction of the peak power consumption which is penalized in the energy contract.

The simulations with Belpex prices show a theoretical cost reduction of 11% calculated in the same way as mentioned in the previous paragraph. Even with a smaller temperature window of 2°C, a cost reduction of 7.3% can already be achieved. This is caused by the higher volatility of the Belpex prices. There are more opportunities within a day to buy energy at lower prices. In combination with wind, the cost reduction is limited to 10.8%. This is caused by the fact that the price difference between the Belpex prices and wind is smaller than in the simulations with a standard contract. Further, there is no peak penalty in the contract. The main profit is made in the simulations with a standard contract by means of a peak power reduction.

2.4.3 Conclusions

The infrastructure of the Norbert Dentressangle cold store fulfills all conditions for exploiting flexibility. The facility consists of a well insulated building with a powerful refrigeration system. In combination with wind energy, the maximum power of the refrigeration can be used efficiently in order to buffer and exploit cheap wind energy.

2.5 Luiknatie

2.5.1 Introduction

Luiknatie offers services ranging from maritime logistics, handling and storage of various goods to traditional land logistics offering customers complete solutions for import and export. One of the activities of Luiknatie is temperature controlled storage. Luiknatie has a cold store facility in the Antwerp harbour with 3 storage cells for cooling and 7 for deep-frozen products. Luiknatie has a quite broad portfolio of products for deep freezing, including chemical products which are not temperature critical.

2.5.2 Investigation summary

Available information
For the investigations at the Luiknatie cold store, the following information was available:

- Detailed information of the refrigeration system
- Energy contracts
- power consumption profile for nearly 3 years
- Average temperature profiles of the storage cells

Power consumption analysis
The power consumption of Luiknatie shows a typical cold store seasonal variation. The power consumption during the summer months is typically 20-30% higher compared to the winter. The analysis shows a typical day pattern with an increasing power consumption from the morning to the early afternoon. In the late afternoon the power consumption decreases till 22:00h. At that time the night tariff starts and Luiknatie actively makes use of the cheaper energy price for deeper cooling. Further it is seen that the energy consumption is relatively “flat” during the weekends indicating that weekend activity is limited. The weekend is also used for deeper cooling.

Quantification of the flexibility
For the Luiknatie case it was difficult to make an accurate estimate of the present flexibility, especially because it is a mixed cooling and deep freezing storage facility. The temperature margins for cooling are typically small and for that reason cooling is not considered as a source of flexibility. Based on the installed compressor power and the discussions with the operational people at Luiknatie, the present flexibility was estimated as a percentage of the total power consumption. Based on these estimations, a simplified cold store model was made for further simulations.

For Luiknatie, 4 scenarios were compared:

- Scenario 1: Simulations with a standard contract and without wind turbine.
- Scenario 2: Simulations with a standard contract and with wind turbine.
- Scenario 3: Simulations with Belpex prices and without wind turbine.
- Scenario 4: Simulations with Belpex prices and with wind turbine.

Again, as in the Norbert Dentressangle simulations, for each scenario, 4 simulations were performed: a reference simulation with a constant temperature of -20^{o}C in the cells, a simulation with a temperature between -20^{o}C and -22^{o}C, a simulation with a temperature between -20^{o}C and -25^{o}C and a simulation where the temperature must be lower than -20^{o}C.

The simulations with a standard contract and without wind turbine show a theoretical cost reduction of 2.7% in case a realistic temperature window of 5°C is used. Simulations show that the cost reduction nearly doesn't change anymore in case the temperature window is further increased. In combination with a wind turbine the theoretical cost reduction increases to 7.1%. This is partially caused by the fact that 6.1% more energy is bought from the wind turbine but mainly due to a 35% reduction of the energy bought during the expensive day tariff and a significant reduction of the peak power consumption which is penalized in the energy contract.

The simulations with Belpex prices show a theoretical cost reduction of 3.5%. In combination with wind, the cost reduction is limited to 3.9%. This is caused by the fact that the price difference between the Belpex prices and wind is smaller than in the simulations with a standard contract. Further, there is no peak penalty in the contract. The main profit is made in the simulations with a standard contract by means of a peak power reduction.

2.5.3 Conclusions

Although Luiknatie and Norbert Dentressangle are both cold stores, the results are pretty different. Most probably due to a lower insulation level and a less powerful refrigeration system, the Luiknatie cold store is not able to achieve the same level of cost reduction compared to Norbert Dentressangle. Nevertheless, the cost reduction remains significantly and especially in case of a standard contract in combination with a wind turbine a decent profit can be realized by means of a demand side management system. The detailed analysis shows, however, that the results for very similar companies differ significantly and an individual screening is mandatory for a proper quantification of the flexibility of each individual case.

2.6 Comparison of the companies flexiblity

Flexibility contains aspects of “time”, “energy” and “power” which are related. The figures below compare the orders of magnitude of these properties for the different companies.

Figure 1 Comparison of the flexibility expressed in “power”.

Figure 2 Comparison of the flexibility expressed in “time”.

Figure 3 Comparison of the flexibility expressed in “energy”.

3 New sources of flexibility

During the interviews and technical meetings in the Port of Antwerp, ideas for new elements in a smart energy network popped up. This section briefly describes 2 new ideas which have a quite ”maritime” touch: ”Reefers” and ”Harbour cranes”.

3.1 Reefers

A lot of the maritime transport of refrigerated goods happens in refrigerated containers, often called ”reefers”. Refrigerated containers need electric power for cooling and have a typical peak power consumption of 10-15kW for operation at temperatures up to 60°C. The average power consumption in a Northern Europe harbour, however, is 3 to 4kW which means that their is a significant overcapacity which can be used in order to create flexibility.

First simulations have showed that the average temperature in a well insulated reefer increases with 1ºC per 5 hours in an outside temperature of 20°C when the reefer is switched off. Under the assumption that a temperature window of 5ºC (e.g. -19 ... -24ºC) is acceptable, this means that it is possible t to maintain the temperature for 24 hours without power. In practice it will be probably less, but there is a potential flexibility in time of at least many hours.

Next, a first estimate of the potential of this concept was made. In 2008, a volume of 250.000 reefer containers was handled in the Port of Antwerp. Taking into account that a reefer container remains 3 to 4 days in the harbour before it is further transported or emptied, this means that on average there are about 2750 reefer ontainers connected to the electricity grid in the Port of Antwerp. Similar numbers are confirmed in [3]. This represents a potential of 25 to 40MW of flexible power, every day present in the Port of Antwerp.

Exploitation of the flexibility implies the possibility to adjust the power consumption of the refrigerated containers in a controlled manner, within the temperature margins of the stored goods. Just ”disconnecting” the reefers from the grid is not an option. Many reefers are already able to communicate with a central monitoring system in the container terminal or on a container vessel. This standardized communication [4] is used in order to monitor the proper operation of each individual reefer. This existing communication infrastructure could be extended in order to create ”smart” reefers which can adapt their power consumption depending on availability and price of electric energy.

Container vessels might also benefit from this concept. Modern container vessels have up to 1000 reefer connection points which represent a tremendous load on the vessels electricity generators. Smart control can equilize electricity consumption over time resulting in peak power reduction, lower emissions and optimal use of the vessels infrastructure.

3.2 Harbour cranes

Still a significant amount of harbour cranes is not connected to the electricity grid. Each crane has its proper electricity generator which is powered by a diesel engine. Typical power of these electricity generators is 100 to 750kW. In practice it is estimated that these cranes are used for about 25% of the time.

The idea consists of connecting these electric generators to the electricity grid at times when they are not in use. This creates a cluster of diesel electric generators which can be used in many ways e.g. support electricity supply in cases when there is a limited amount of electric power available, sell electric power when the prices are high on the energy market(s).

4 Conclusions

Analyses on the presence of demand side flexibility in the Port of Antwerp have been performed in 2011 and 2012. Five companies participated in this project i.e. Amoras, Borealis, Luiknatie, Norbert Dentressangle and SEA-invest. For the 5 companies participating in this project, a technical and economic analysis has been carried out on the search for demand side flexibility. From the 6 possible universal business cases [1], two business cases were examined which don't require clustering i.e. *contract optimization*, and *trade on the wholesale market* (short term spot market) in combination with local wind balancing. Cluster related business cases are discussed in [2].

For most companies 4 scenario's were calculated:

- Scenario 1: scenario **without** wind energy but making optimal use of the flexibility within the margins of the current energy contract
- Scenario 2: scenario **with** wind energy but making optimal use of the flexibility within the margins of the current energy contract
- Scenario 3: scenario **without** wind energy but making optimal use of the flexibility for buying energy at the Belpex energy market
- Scenario 4: scenario **with** wind energy but making optimal use of the flexibility for buying energy at the Belpex energy market

Summary of the company results

- SEA-invest: Product quality constraints result in very tight temperature limits in cooling houses and consequently no flexibility was identified
- Amoras: Amoras has a huge flexibility in "time", "power" and "energy" and is well suited for local wind balancing. Present operational constraints must be investigated in order to achieve a valid business case.
- Borealis: Borealis has a large flexibility in "power", but limited in "time" which gives limited possibilities for local wind balancing. The flexibility could be exploited in other ways, but operational constraints prevent exploiting flexibility at this moment, or should be examined further.
- Norbert Dentressangle: The modern infrastructure is perfectly suited for local wind balancing. Theoretical energy cost reductions up to 15% can be achieved in a local wind balancing case.
- Luiknatie: The infrastructure is a bit older and less powerful compared to Norbert Dentressangle. Nevertheless a theoretical energy cost reduction of 7% is still possible.

Overall, there seems to be a business case for 3 out of 5 companies. For Norbert Dentressangle and Luiknatie, the implementation of a control system needed for the exploitation of the flexibility is from technical point of view quite straightforward. For Amoras, some organizational constraints must be solved in order to achieve a workable automated demand side management system. Because the yearly energy cost reduction is significant, it is realistic to assume that a solution can be found which still results in a valid business case. In all investigations, the investment costs and the return on investment was not studied.

5 Lessons learned

Already today, within the existing contracts, there is margin for some companies to financially benefit from active flexibility management. Especially in combination with local renewable energy sources a significant energy cost reduction can be achieved.

Flexibility is a new and ”unknown” product which is typically not assessed and quantified during standard energy audits. Examples as Amoras and Borealis show that flexibility is present also in installations were it is not expected. Many companies don't realize what ”flexibility” exactly means and they don't realize the potential economic value especially towards the future. Due to this lack of knowledge an active search for flexibility remains neccesary in order to create awareness of the potential value. Projects, as e-harours, are helping in order to create this awareness.

Although flexibility is found in many installations, companies are still reluctant to exploit it. It's a new way of thinking about energy, it requires changes in their installations and they consider it a risk for the continuitity in their activities. Operational cost reduction is an important consideration in most companies, but flexibility is a relative complex product which in the end is not their core business. Further, many modern company structures result in well defined entities with their proper targets and responsibilities. Exploitation of flexibility might be profitable, but the ”benefit” and ”burden” are not necessarily in the same entity.

Current installations are not designed and built with ”flexibility” in mind. Quite often, a small change in the installation can improve the flexibility of the installation significantly. For many practical reasons (no place for expansion, installation is in continuous operation, ...) it is sometimes difficult to apply these small changes to existing installations. For that reason, it is important to consider the limited extra cost for flexibility in the design phase of an installation when new investements are planned.

Ideas for further investigation

Based on an initial analysis, there seems to be a potential value in the use of flexibility available in reefers in the harbours area. In case communication with the reefers is possible, it might also be interesting to use this communication channel to coordinate the switching of the reefers while on board a ship.

The same is applicable for the grid connection of harbor cranes. The amount of electrical power available in the diesel driven generators of these cranes is significant and could contribute to the deferral of investments in network infrastructure. Investigation to the potential of reefers and cranes as part of a VPP.

6 References

[1] E-harbours deliverable 3.4, *"Strategies and Business Cases for Smart Energy Networks"*, available at http://eharbours.eu/wp-content/uploads/e-harbours_Strategies-and-Business-Cases-for-Smart-Energy-Networks_wp3_4.pdf

[2] E-harbours deliverable 3.5, *"Application of Smart Energy Networks – part II: Cluster analysis of the combined company flexibility in the Port of Antwerp"*

[3] *"Rotterdam is cool"*, Dutch Daily News available at http://www.dutchdailynews.com/rotterdam-is-cool/

[4] "*ISO 10368:2006 – Freight thermal containers – Remote condition monitoring* ", available at http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=36595