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WP 3.5 Application of Smart Energy Networks

Technical and Economic Analysis

Summary results of showcase “Search for flexibility provided by electric boats in Amsterdam”

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1.1 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 both technical/economical and organisational/legislative conditions is crucial.

The e-harbours report 3.7 focuses on the *organizational and legislative aspects* of smart energy solutions. A long list of general barriers has already been composed (deliverable 3.3).
The report 3.7 addresses the analysis on a local basis (country/city/harbour), where the smart energy solutions are hampered.

This e-harbours report 3.5 focuses on the *technical and economical aspects* of smart energy solutions. The scope of WP3.5 is the translation of the 6 universal business cases (e-harbours report WP3.4) on the level of every showcase. It gives an overview of the potential for the exploitation within the existing local (national) rules and regulations.

This document summarizes the results for each of the showcase in Amsterdam.

Universal business cases: 6 possibilities defined

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:

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. Offer further grid stabilization services: Large scale producers and consumers can offer flexibility for reactive power balancing or preventing congestion of the transmission grid.

1.2 The strategy in showcase "Search for flexibility provided by electric boats in Amsterdam"

The strategy was to combine theory based on reports by Waterrecreatie advies and TNO (Centre for Applied Scientific Research), with input based on interviews with a boating company, an aggregator and an association.

We interviewed a company in the field of electric boating, in order to find out whether companies are interested in the smart grid concept. We also interviewed an "aggregator", a commercial party which is authorized to trade on the wholesale market on behalf of a pool of customers.

Furthermore, we had contact with the association of electric boating "Vereniging Electrisch Varen Nederland". (http://www.ev-nl.nl/).

We also studied documents. First a policy document of the Water authority of Amsterdam ("Nota Varen in Amsterdam") in which emission- targets for boats are formulated for the coming years. This in order to estimate the coming developments in electric boating. We also got information about the current state of electric canal cruising and the consequences for business operations from two investigations (conducted by interviewing the branch), completed by Waterrecreatie Advies and TNO.

1.3 Scope of the e-harbours showcase "Search for flexibility provided by electric boats in Amsterdam"

The Amsterdam canal boats are number 1 tourist attraction in the Netherlands (over 3 million visitors a year). Given the large scale of boating, approximately 250 boats for commercial use (canal cruise boats an rental boats) and 14.000 small leisure boats (owned by citizens of Amsterdam) the transfer to electric boating could contribute to the air quality in Amsterdam and to flexibility of energy use (smart grids) on the long run. The Amsterdam canal boats could potentially be an interesting energy buffer, consuming the energy during low demand hours or when local renewables are in excess. The scope of this case study was to estimate the potential of flexibility provided by electric boats in Amsterdam if all boats become electric.

Deliverables:

- This report
- Brochure Smart Grid
- Factsheet Smart Grid
- Minutes meeting Greenjoy (26-08-2013)
- Report "Rondvaart en Recreatievaart in Amsterdam"
- Report "Elektrisch varen in de Amsterdamse Grachten"
- Presentations at the expert meeting of September 9th

1.4 Optional: Extended/limited scope

The original scope was to develop a Smart Marina Overamstel. Projectbureau Wibaut aan de Amstel - responsible for the development of the Overamstel area - and the Air quality Department worked together to develop a sustainable marina in the Overamstel area. The idea was to tender the exploitation of the sustainable marina, whereby the winner should be allowed to build and manage the marina. In line with the e-harbours project the original idea was to include sustainability as a selection criterion for the project plans. The presence of a smart grid solution, a rental company of 20-30 electric boats and a solar power installation with a smart charging infrastructure could provide significant scoring advantage in the tender. In order to inform the tenderers and help them with the smart grid development, various brochures were written by Projectbureau Wibaut aan de Amstel and the Airquality Department in collaboration with a smart grid expert (see above "deliverables": factsheet Smart Marina and Brochure Smart grid").

The flexibility for the smart grid system in the Overamstel Marina could be provided by the 20-30 electric rental boats. By linking the electric boats to locally generated energy, an optimum balance could be achieved with a smart grid. To provide the flexibility for the smart grid system, the electric rental boats were an essential part of the smart marina tender. Unfortunately, a legal problem arose for the Smart Marina business case. Waternet (the Water Authority of Amsterdam) has put a stop on licensing boats, also electric boats (so also the 20-30 electric rental boats that were part of the Smart Marina Show case). The envisioned electric rental boats in the case of the Smart Marina were needed in order to provide the flexibility in the Smart Grid. Without the electric rental boats, the number of electric boats in the marina is too insecure to create flexibility. Concluding: without the licenses for 20-30 electric rental boats it was not reasonable to give extra scoring points on smart solutions in the tender and there was no proper business model for smart grids left. In 2012 extensive research has been done to find a solution, but it appeared to be a very complicated legal matter and a hot political topic as well. In April 2013, the definite conclusion of Projectbureau Wibaut aan de Amstel was that they would eliminate "the presence of a mart grid" as a selection criterion.

Despite the fact that the Overamstel Smart Marina will not be developed anymore, the Air quality department had the opinion that it's important to learn lessons anyway. Therefore, the Air quality department hired smart grid expertise and interviewed different parties in order to estimate the potential of a smart grids based on electric boats. Given the large scale of boating in Amsterdam, the transfer to electric boating is interesting for the e-harbours project. Apart from the fact that it has a direct influence on air quality the transfer can contribute to flexibility of energy use (smart grids) on the long run.

2 RESULTS

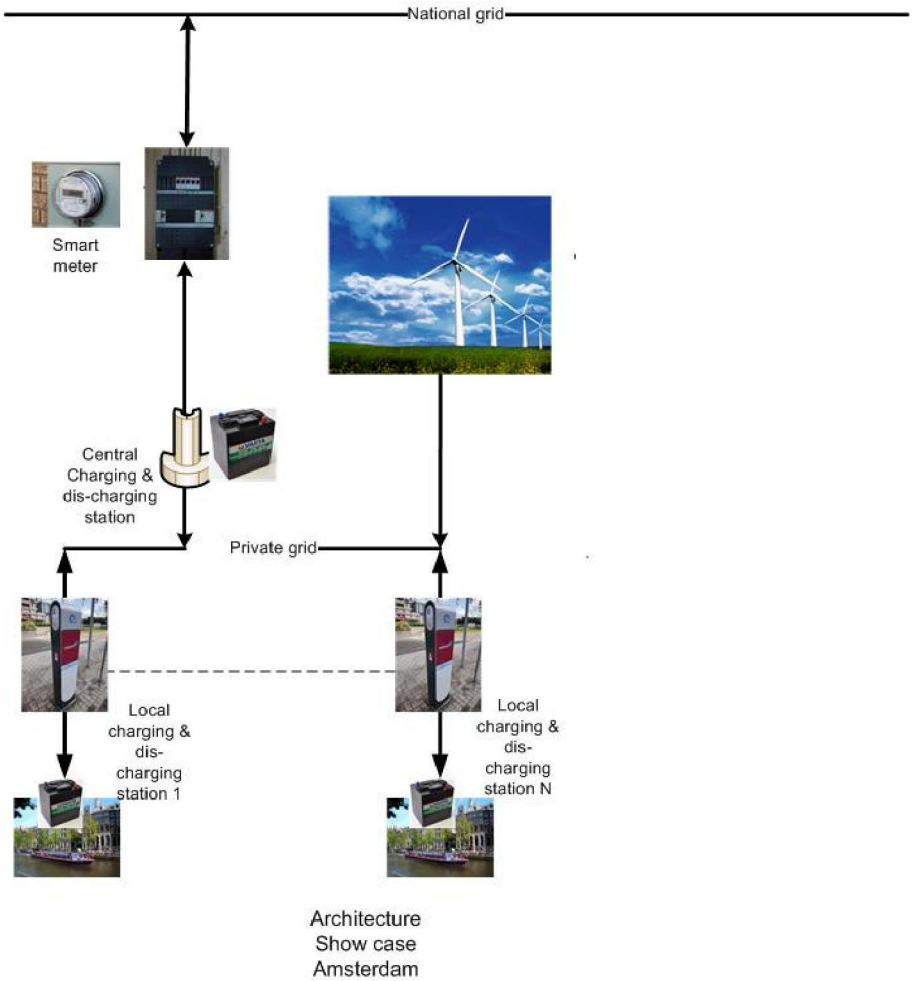
2.1 Case study electric boating

2.1.1 Introduction

The scope of this case study was to estimate the potential of flexibility provided by electric boats in Amsterdam if all boats become electric. Given the large scale of boating in Amsterdam, the transfer to electric boating is interesting for the e-harbours project. Apart from the fact that it has a direct influence on air quality the transfer can contribute to flexibility of energy use (smart grids) on the long run.

We have analysed the following 6 scenarios using standard tariff as the base line scenario.

1. Local level: Optimizing battery charging process based on
    a. day night tariff
    b. day night tariff plus wind energy
2. On cluster level: Optimizing battery charging process based on
    c. day night tariff
    d. day night tariff, plus wind energy
    e. wholesale market (APX tariffs)
    f. wholesale market (APX tariffs), plus wind energy



Configuration(s) of possible smart grid electric boating

2.1.2 Investigation summary and conclusion

Available information

- Interview with Greenjoy
- Interview with Aggregator company
- Contact with the association of electric boating "Vereniging Electrisch Varen Nederland". (http://www.ev-nl.nl/), they gave information in order to verify the assumptions made as preconditions for the analysis.
- Reports and presentations of TNO (Centre for Applied Scientific Research) and Waterrecreatie advies

Preconditions analyses

- The electric boats are only operational during spring and summer season. The exploitation of autumn and winter period is not clear, but could become part of another virtual power plant (see ideas for further investigation).
- The batteries of the boats are only charged during evening and night time. They are not connected with a charging infrastructure during the trips.
- Base line scenario. For the determination of the amount of flexibility as defined by RGU for the benchmarking, the non-smart charging option for each scenario is used as the base line.

Tariff structure applied for the simulations and analyses of the business cases:

Standard tariff	: 0,059 Euro/kWh
Peak or day tariff	: 0,065 Euro/kWh
Off peak or night tariff	: 0,049 Euro/kWh
Wind tariff	: 0,06 Euro/kWh
Tax 1	: 0,11 Euro (usage <10000 kWh/year)
Tax 2	: 0,05 Euro (usage >10000 kWh/year)
Tax 3	: 0,01 Euro (usage >50000 kWh/year)
Fixed tariffs	: 380 Euro discount on "tax 1" user, discount 175 Euro "tax 2" user, per grid connection
Whole sale market	: APX the Netherlands based on 2012 tariffs.

Battery specifications

Based on the theoretical assumptions, the total capacity of a battery is 100% and it could be charged to 100% in, for instance, 1 hour. However, based on the battery type used, these parameters are lower. Also keep in mind the limited allowable amount of charge cycles of a battery. The life time of a battery is also influenced by the charging algorithm of the smart grid charger. For the analyses we assume an battery charge/discharge cycle efficiency of 90%, lowest state of charge: 20%.

In the following paragraphs the business cases on "local" and "cluster" level are described, and some reflections on *balancing group settlement*. "Local" means: exploiting the business cases for a small fleet of boats at 1 geographical location using one grid connection but a energy usage of >10000 kWh/year. Cluster level means: a so called virtual power plant of one or more boats, on more than one geographical location. We assume that both on local and cluster level taxes are the same i.e. 175 Euro fixed discount , and 0,05 Euro tax per kWh.

Analysis 1: Local level

For estimating the potential of this business case we assume that the boats are coupled via a standard grid connection. A connection comparable with a stand house hold.

Today the company Greenjoy handles a standard tariff structure. We considered using day/night tariff optimisation. Knowing that the boats are charged only during evening and night time this seems to be an obvious scenario. A virtual "smart grid controller" takes care of the charging algorithm.

The results of the analyses show:

a. Optimizing on day night tariff the financial gain will be 10%.
b. Optimizing on wind energy, and day night tariff the financial gain will be 13%.

The exploitation of flexibility, by smart charging, contributes to a cost reduction of: 4 and 6 %.

NOTE1: The financial gain between the base and case a and b, show that only 50% of the tariff-difference between peak and off peak tariffs (which is almost 20%) can be exploited. This is caused by the fixed part of the energy price (that are the energy taxes and transport fees: more than 100% on top of the energy price) for small consumers (<10000 kWh) in the Netherlands. For large consumers the picture is quite different (see chapter conclusions). Secondary effect is that during normal charging hours a part of the off peak period will be consumed as well.

NOTE 2: In the Netherlands two off peak time slots are defined: between 9 pm and 7 am, and 23pm and 7 am. For our calculations we assumed the second time slot.

NOTE 3: Trading on the whole sale market is a hypethetical option because it is only an option when the total energy consumption is high enough to be a partner on the whole sale market.

Analysis 2: Cluster level

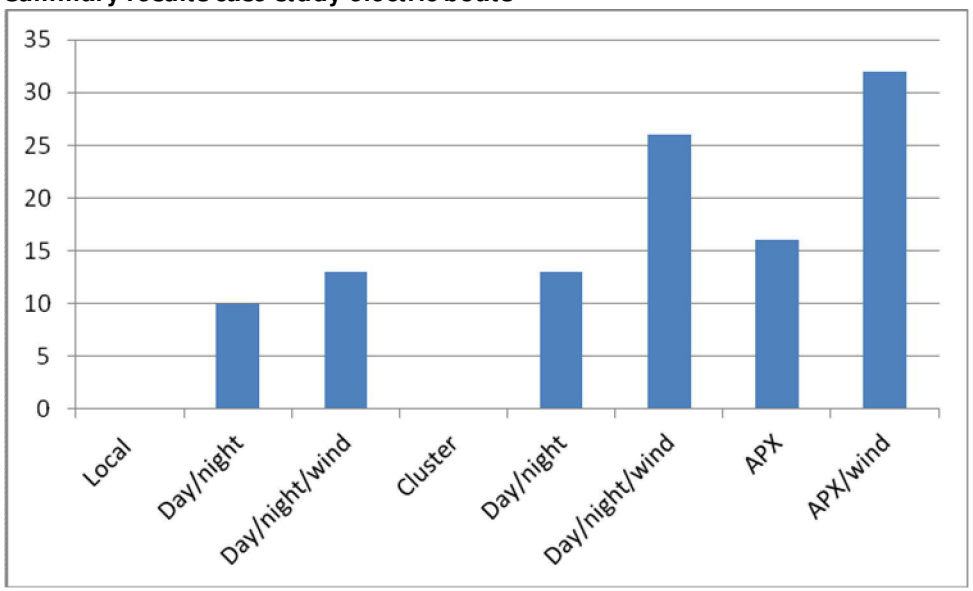
In order to become part of the wholesale market we assumed a virtual cluster of boats located on one or many different locations in the Netherlands. Second assumption is that the cluster may be considered as one legal entity which is responsible an accountable on behalf of the total fleet of boats or the participating fleet owners. This entity could be one company or an association representing the cluster. Keep in mind that the tax tariffs for users >10000 are significantly lower. We also assume that the wind turbines are regarded as part of the legal entity i.e. part of private network. Under the present circumstances in the Netherlands this is not accepted. For the calculations we implemented a smart charging scenario optimising the best financial gains.

a. Optimizing on day night tariff the financial gain will be 13%.
b. Optimizing and trading on the whole sale market the financial gain will be 26%.
c. Optimizing on day night tariff and wind energy the financial gain will be 16%.
d. Optimizing on wind energy and trading on the whole sale market the financial gain will be 32%.

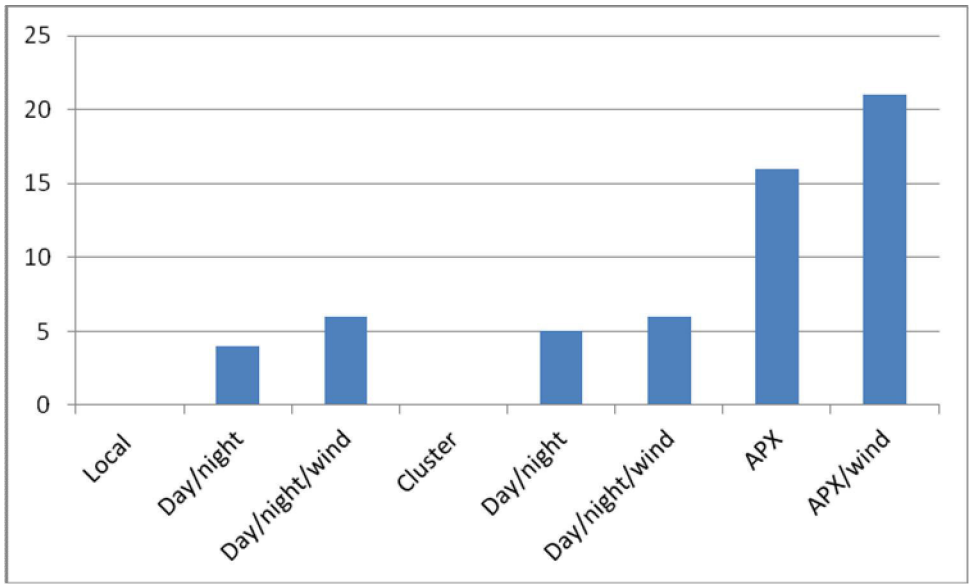
The exploitation of flexibility, by smart charging, contributes to a cost reduction of: 5, 6, 16, 21 %.

We also discussed the possibilities to exploit the potential of flexibility with a commercial party in the Netherlands. This company is a so called aggregator which is authorized to trade on the wholesale market on behalf of a pool of customers. The big question was: is there a product on the market which can act on the balancing market and offer reserve capacity to the grid. Answer: they have plans for the future but presently, acting on the reserve market is not an option.

Summary results case study electric boats



The percentage of financial cost saving on energy bill per boat per scenario.



Contribution cost saving on energy bill due to exploitation of flexibility.

Upscaling scenario's

Dutch potential reserve capacity

We had contact with the association of electric boating "Vereniging Electrisch Varen Nederland". (http://www.ev-nl.nl/). They gave information in order to verify the assumptions made as preconditions for the analysis. Based on estimations of VEVN the potential off the current number of electric boats in the Netherlands is 2000-3000. The average capacity of a boat is 20 kWh, which means that theoretically the boats represent an energy pool of more than 40 MWh. The estimated real time power is in the order of 8-12 MWatt.

Amsterdam future potential
Based on the current numbers of the Amsterdam fleet, the potential number of electric boats in Amsterdam is 200 canal cruise boats and approx. 14.000 small leisure boats. Theoretically the Amsterdam fleet represent an energy pool of more than 60 MWh (see table below).

Possible scale if all Amsterdam boats become electric				
	Needed battery	How to charge?	Number	KWh
Small private leisure boats	1-3 KWh	Charge at home	12.500	Not relevant, not in cluster
Private leisure boats	10-20 KWh (average 15 KWh)	Public charging	1.500	22.500 KWh
Bigger commercial boats	150-250 KWh (average 200 KWh)	Private charging (cluster) or public charging	200	40.000 KWh
Total (rounded)				63 MWh

This is just an estimation, based on the current number of boats in Amsterdam and given the fact that Amsterdam is tightening the rules for licences to ban fossile fuel motors from the canals in the coming 10 to 15 years.

Stakeholder meetings
We had meetings with the following parties:

- Greenjoy electric boating company (minutes available)
- Aggregator company (email correspondence)
- We had contact with the association of electric boating "Vereniging Electrisch Varen Nederland". (http://www.ev-nl.nl/), they provided figures on the numer of boats, and their battery capacity, used as preconditions for the upscaling (email correspondence with boating information).
- TNO presentation and telephone call.
- Consult Waterrecreatie (report)

3 Overall conclusions

The case study shows that the batteries of the electric boats offer a great potential for flexibility, and could be exploited as part of a smart grid application. Local optimisation can be implemented without changing Dutch laws, however integrating wind energy can only be exploited in case the turbine is located at the local estate, and regarded as part of a private grid.

The cluster application also has an even higher potential being part of a grid balancing business case, however we assumed for the sake for the analysis, that clustering consumers and producers dispersed over the region would be an option. This is not yet the case yet, this option would be very important to enable exploiting balancing group settlement.

4 Lessons learned

4.1 Technical issues

Based on the interview with our stakeholders we conclude that technical issues are not the show stopper of using electric boats as part of a smart grid. The electric boats are all equipped with an adequate ICT infrastructure that has enough functionality to support the implementation of a smart

grid application (remote monitoring and control: real time remotely charging and discharging batteries).
Chargers should be upgraded to higher charging currents, and for exploiting balancing group settlement be replaced by charge-discharg devices.

4.2 Economic issues

The analyses of the different scenario's show that there are viable business cases, using both local and cluster optimisation. However the big question remains whether the gain is high enough to cover possible extra investements.

4.3 Ideas for further investigation

1. Search for more combinations and types and mixes of business models: think about the option of being able to exploit the flexibility only during autumn and winter time.
2. Investigate legislative options for associations in order to unite companies to organise a cluster, as one authority.
3. Finding coalitions with network owners to integrate the battery capacity on the grid, by for instance integrating the batteries in or nearby a distribution station.

5 References

[1] Minutes meeting Greenjoy, 26 August 2013
[2] meeting with Power house, 3 October 2013
[3] Report Waterrecreatie Advies, "rondvaart en recreatievaart in Amsterdam", 1 November 2012
[4] Report Waterrecreatie Advies, "Elektrisch varen in de Amsterdamse Rondvaart", 4 September 2013
[5] Presentation TNO (Centre for Applied Scientific Research), "Schone aandrijving voor de Amsterdamse rondvaart", 9 September 2013
[6] Waternet (Water Authority Amsterdam), "Nota Varen in Amsterdam 2.0", September 2013
[7] e-mails "Vereniging Electrisch Varen Nederland".

e-harbours electric

WP 3.5
Application of Smart Energy Networks

Technical and Economic Analysis

Summary results show case Port of Antwerp
Part I: Individual company demand response audits

Jef Verbeeck, Fred Kuijper

Photo: Colourbox

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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: 6 possibilities defined

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 – Show case the Port of Antwerp Part I: Summary results of the individual company demand response audits** (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 – Show case the Port of Antwerp part II: Cluster analysis of the combined company flexibility**: In this document the flexibility of all screened companies is combined into a Virtual Power Plant (VPP) [2].

1.1 Strategy of the showcase

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%.

1.2 Scope of the e-harbours show case

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.

1.3 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 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.

- Manual operated terminal: 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:

- Standard energy contract: 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%.
- Local wind energy optimization: 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:

- 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.

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°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 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 1°C per 5 hours in an outside temperature of 20°C when the reefer is switched off. Under the assumption that a temperature window of 5°C (e.g. -19 ... -24°C) 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 Overall 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

e-harbours electric

e-harbours

WP 3.5 Application of Smart Energy Networks

Technical and Economic Analysis
Summary results of the Hamburg showcase

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The Interreg IVB North Sea Region Programme
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ZNSTD

1.1 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 both technical/economical and organisational/legislative conditions is crucial.

This e-harbours report 3.5 focuses on the *technical and economical aspects* of smart energy solutions. The scope of WP3.5 is the translation of the 6 universal business cases (e-harbours report WP3.4) on the level of every showcase. It gives an overview of the potential for the exploitation within the existing local (national) rules and regulations.

The e-harbours report 3.7 focuses on the *organizational and legislative aspects* of smart energy solutions. A long list of general barriers has already been composed (deliverable 3.3).
The report 3.7 addresses the analysis on a local basis (country/city/harbour), where the smart energy solutions are hampered.

Universal business cases: 6 possibilities defined

The final document of WP3.4, "Strategies and Business Cases for Smart Energy Networks" [EHAR 2013], 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 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 report. This report summarizes the following cases:

1. 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.

2. 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.

3. 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.

4. Offer reserve capacity: In case BRP's are not able to maintain the system balance, the transmission system operator (TSO) has to use 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.

5. 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.

6. Offer further grid stabilization services: Large scale producers and consumers can offer flexibility for reactive power balancing or preventing congestion of the transmission grid.

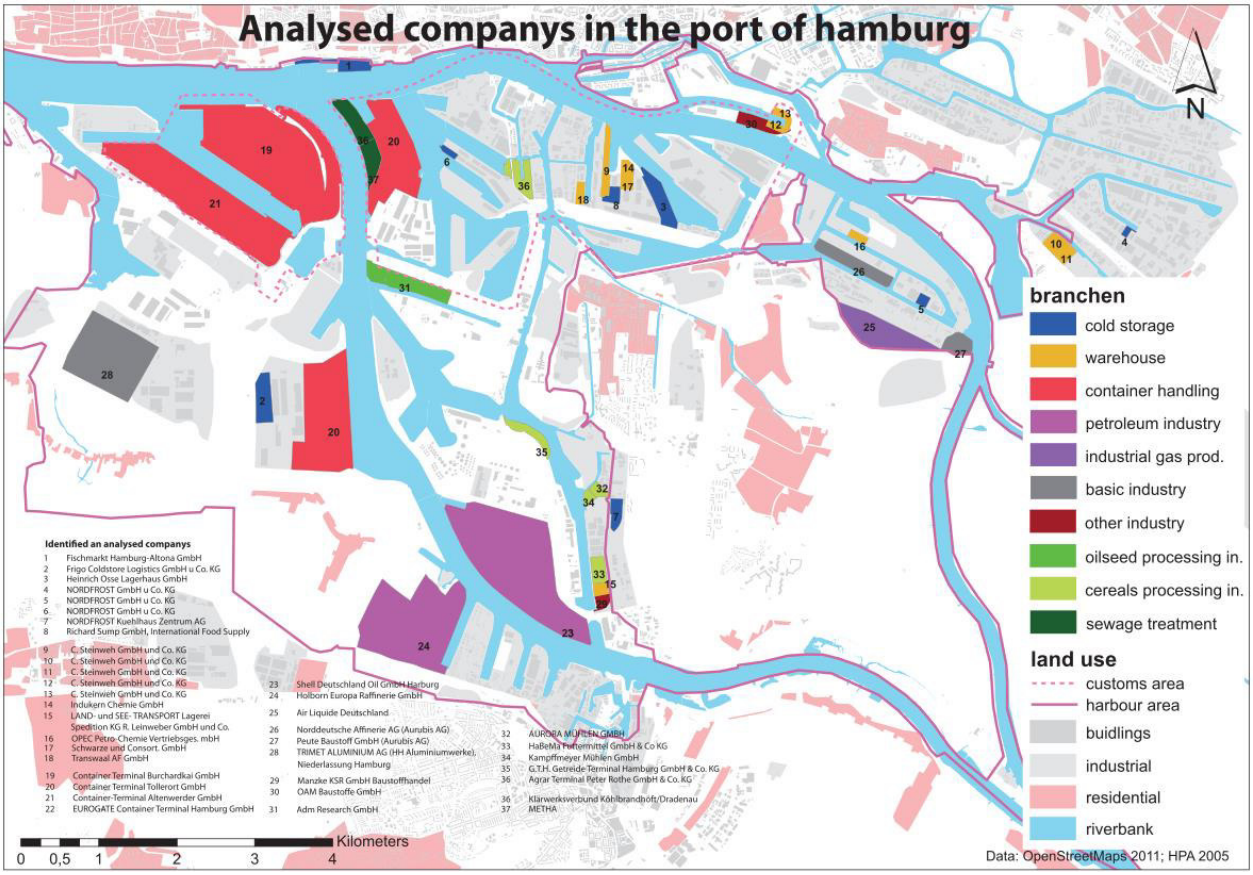
The scope of this report WP3.5 is the translation of the “theoretical” business cases of WP3.4 into realistic busines cases in a harbour context.

1.2 The strategy in the Hamburg showcase:

Starting point for the Hamburg showcase was to gain an overview of basic characteristics of energy consumers typically found in harbour areas. As a preparation, the Hamburg project team conducted a literature research regarding common sources of flexibility as well as typical flexibility within different consumers regarding shiftable loads and time.

A property analysis within the Hamburg harbour area was then commissioned. It included the Identification of industrial/commercial properties and a rough estimation of flexible potentials within each property, either by publicly available data on energy consumption and/or rule-of-thumb values for different industries provided by literature.

Results were included in a spatial visualisation by a GIS map, differentiated by types of industrial/commercial usage.
As a conclusion, the overall load shift potential of all the identified properties was estimated.



Overview of analyzed companies within the property analysis. Source: Own elaboration

Next step in the Hamburg showcase was the selection of properties from different sectors: Industrial, commercial and harbour infrastructure. Mainly companies were contacted with whom personal contacts from other activities existed.
Four companies agreed to cooperate: Direct cooperation was established with a chemical production company and a terminal operator. Cooperation with two cold storage operators was initiated with the help of an external consultant (energy&meteo), who has vast experiences in the field of cold storage energy concepts.

Identification of flexibility

First appointments with energy managers were scheduled to get a first impression of the companies' energy consumers and the related processes, own production capacities as well as their interests and priorities concerning smart energy solutions.
In all showcase properties, one or more on-site visits were conducted in order to get an impression of the most important energy consumers and flexible potentials and their integration within the respective processes or applications.

Detailed data on energy loads were then requested: In Germany, larger consumers are billed according to measured load and consumption; measurement data in 15min. intervals are made available by the power supplier. If available, more detailed measurement data on electrical loads or process data recorded by the facility operator were made available. Furthermore information on energy contract for electricity and gas as well as technical information on grid connection were requested.

Quantification of the flexibility

For all showcase properties, identified suitable consumers (and in some cases generation capacities) were analysed in-depth regarding their available flexibility. Together with companies' technicians and process specialists, operation profiles were created and possible buffers and flexibilities in the underlying processes evaluated. In one case, own measurement equipment was installed in order to get detailed load and consumption data for separate consumers or groups of consumers.

Where necessary, simulations were conducted to assess maximum shiftable loads and time periods. Where thermal consumers (heating/cooling applications) were involved, a thermodynamic model was developed. It serves to assess the flexibility in cooling operation within the permitted temperature boundaries and related to outside temperatures. Simulations were conducted over the time of a year in order to analyse changes due to varying parameters like the ambient temperature.

Valorisation of the flexibility

On the basis of the provided data and the simulation results, feasible smart energy applications and related business cases were identified. On the basis of the above mentioned simulation models, the properties' historical load data and historical energy market data timelines, possible returns for different business cases were calculated, usually over the period of one year. Were necessary, an optimization algorithm was used to ensure the ideal operation strategy for the smart energy network. Herein, safety margins and uncertainties that would also occur during normal operation were reflected.

Economic potentials were then presented to the companies in a meeting, giving company representatives the opportunity to comment on the quality of assumptions taken. If necessary, models and calculation methods were revised and results updated.

Exploitation of the flexibility

In case that companies showed interest in the realization of some or all elements of the presented solutions, in-depth consulting was offered: This included calculation of necessary investments, exploration of non-technical barriers for implementation and, if demanded, establishment of contacts to professional providers and contractors.
This process is still on-going in some of the showcase objects, but promising steps towards the exploitation of flexibility have been made in most cases.

1.3 Scope of the e-harbours showcase in Hamburg

The e-harbours Hamburg showcase focuses on the application of smart energy solutions in large-scale industrial, commercial and infrastructural properties in a typical harbour environment.

The solutions that are taken into consideration cover a wide range: Local load shifting mechanisms, integration of local consumption and/or production devices into a virtual power plant, combined generation to cover power and heat demand, and options for energy storage in the form of electricity, heat or cold.

Although technical possibilities are assessed within each case study, the economic viability of smart energy solutions lies at the centre of attention, following the question: What makes a smart grid profitable? The target is therefore not to build technically viable demonstrators, but to introduce and assess smart energy solutions in today's market-based environment and in accordance to companies' expectations regarding return on investment, operational security etc.

2 SUMMARY RESULTS

2.1 Chemical production company

2.1.1 Introduction

The company operates a medium-to-large production plant in the Hamburg Harbour, where it produces a broad range of semi-finished goods from raw materials. Due to a non-disclosure agreement, the full name and precise data on the company may not be published.
The plant is operating continuously, but production is organized manually in batches. Production steps vary according to the specific products.

2.1.2 Investigation summary

Available information

Data that was made available include electric load profiles over several years on a 15-minute timescale, gas demand profiles (used for process heating) on a 60-minute basis, power and gas contract data etc.
Besides, technical layout data concerning a CHP plant that became operational in 2013 was provided (see below).
Also, data on hydrogen supply was made available, including volume and prices (on hydrogen use, see next paragraph).
Unfortunately, no load data was available for smaller parts or even single consumers within the property. However, motivated by the insights gained through the e-harbours project, the company is currently planning to introduce an energy management system, which will be able to provide detailed load data. Unfortunately, the system will not become operational within the e-harbours project runtime.

Power consumption analysis

Core power consumers are agitators and pumps for fluid or semi-fluid materials.
Another large set of consumers are compressors used in a central cooling system, which is used to cool down material between production steps.

Characteristics include a significant heat demand, which is largely stable on a daily, weekly, and even seasonal scale. Heat is distributed by a steam grid on the company's premises.

Another notable and very interesting detail is the plant's high demand for hydrogen, which is used as a production input. Hydrogen demand is stable over time, and is currently met by delivering large quantities of hydrogen by truck. It was decided to investigate the option for producing hydrogen on-site via electrolysis, which would represent a large consumer that could be flexibly operated in order to increase overall flexibility at the site.

Quantification of the flexibility

Heat at the facility was traditionally produced by large gas-fired boilers. In order to meet the heat demand more efficiently, the company recently installed a large gas-powered CHP plant to cover a

large share of the heat demand. In addition, during most of the year, the CHP plant produces more electricity than is consumed, which makes this industrial property a net power producer from a grid point of view. As the earlier used gas boilers are still in place and operational, there is a large flexible potential on the power side, by regulating down the CHP temporarily and covering the heat demand using the boilers. In this concept no storage capacity whatsoever is needed as the heat demand is directly substituted by an additional heat producer.
By turning down the CHP a reduction of production in the magnitude of several MW can be provided for several minutes to several hours. Reaction time of the CHP is rather fast, and is sufficient for tertiary or even secondary reserve capacity provision (on the different types of reserve capacity, see [EHAR 2012]). The provision of (negative) reserve capacity therefore represents the central business case for this case study.

Flexibility could be increased a lot more if **electric heaters** would be installed to temporarily cover heat demand when the CHP is turned down, instead of gas boilers. Thus, in addition to switching off the CHP as a power producer, electric heaters generate an extra load. The reduced production of the CHP and the consumption of the electric heater add up to a total potential which would more than double the now available flexible load and thus the amount of negative reserve capacity to be offered.

The **central cooling system** shows some interesting potential for flexible operation. During the plant visit it became clear that the compressor capacity is largely over dimensioned – a good basis for a supply-driven operation strategy. However, the current system will be replaced by a more efficient and modern one in the medium future. Here, recommendations were formulated by the e-harbours team regarding a flexibility-providing design and layout of the new system, for example through the inclusion of a phase change material (PCM) storage device, which would allow the storage of cold.

Exploitable flexibility of other consumers at the facility was found to be rather limited, including mixing rotors and pumps. This is due to their rather intermittent and random operation within the production process, which is partly manually controlled. Although flexibility is available in theory, exploitation would require a major logistic and investment effort in order to control the many dispersed and autonomous consumers.

2.1.3 Conclusions

Possible revenues:

Economic potentials of the flexibility provided by the CHP are substantial and already merit exploitation, e.g. via a reserve capacity pool. With an additional electrical heat production system installed, flexibility would be greatly increased and financial benefits would be almost doubled. The investments needed for an electrical heating system are rather modest compared to the revenues from the provision of reserve capacity.

Implementation:

The company has decided to actively assess the realization of the business case suggested by the e-harbours team and is already in contact with a professional provider of such a smart energy solution. Organisational and administrative issues of the showcase are discussed in the Activity 3.7 report.

Scaling-up potential

Installation of own CHP capacity has become increasingly popular in industrial and commercial properties, due to comparative cost advantages compared to grid power, and also a subsidy mechanism. Crucial point of CHP planning is the heat demand at a property – in order to make full use of the CHP capacity, a significant heat demand is necessary which is not only limited to winter months.
In a smart energy system, CHP operation would be oriented to requirements on the power side – in contrast to a classic CHP operation strategy that is heat-oriented. In order to allow this, heat supply must be secured for times when the CHP is not running. This is possible via heat storage, or, as in the showcase, a substitute with conventional heat generation. If these requirements are met, virtually any grid-connected CHP can be integrated in reserve capacity pools, for example.
The biggest revenues are possible for large CHP plants with a capacity of over 5 MWel that can participate directly on the reserve capacity market. Such CHPs are increasingly found in larger industrial complexes of various sectors – the total installed capacity of large CHP amounts to several GW.

The potential for the installation of electric heating devices for **power-to-heat**-applications is also enormous – given the low investment costs, retrofitting of existing CHP installations or even traditional heat production is thinkable.

Although in the present case **the on-site production of hydrogen** does not have a financial benefit due to favourable procurement conditions on the market, the concept seems promising – especially in the face of rapidly maturing electrolysation technologies. Motivated by this case, the e-harbours team has further investigated the harbour-wide potentials of on-site hydrogen production: Based on a questionnaire sent to various industrial companies in the harbour, a report was produced assessing the technical and economic potentials of this application [HEY 2013].

2.2 Container Terminal

2.2.1 Introduction

Second case study within the Hamburg showcase is a container terminal in the port of Hamburg. It is the most modern of several terminals in Hamburg. With a yearly cargo capacity of 2-3 mio TEUs, it is also a rather large terminal.
The terminal's loading infrastructure (container and storage bridges) are completely electrified, and are largely controlled automatically, i.e. without a human operator steering the crane.

The terminal operator is traditionally very engaged in increasing efficiency and reducing ecologic impacts of its facilities. Also, they are considering several options for on-site production of electricity. Concerning grid infrastructure, none of the terminals in Hamburg is facing physical load constraints. However, peak-load related costs for grid utilization are quite substantial. In addition, the German grid code foresees further reductions in grid utilization costs if the load curve of a consumer is largely stable over the year. Together, this makes quite a strong case for load shifting operations. Another aspect that is also relevant in the case of some container terminals is a peak/off-peak tariff, where off-peak prices per kWh are slightly lower than during peak times.

2.2.2 Investigation summary

Available information

As for all larger customers, load profiles for the whole property are available on a 15-min. base for several years. Also, information on energy contract details was provided.

Regarding the loads caused by different consumers on the terminal, only very rough estimations were available, since they are not currently measured and logged for single parts of the terminal or even separate consumers. Simply put, the terminal operator was not able to clearly quantify what consumers cause the largest amount of load, and which of them are responsible in which degree for load peaks. This lack of detailed data made a proper analysis of flexibility impossible. Therefore, it was decided to install measurement equipment at the terminal.

A measurement concept was developed together with an external consultant on what measurement points to take and how to combine data afterwards. Data storage was organized based on a concept for an IT structure developed earlier in the project.

The project partner undertook the installation of measurement equipment based on the measurement concept. Currently, data is collected on 30 measurement points: It is planned to continue measurements over a few months in order to capture effects by seasonal changes in terminal turnover and ambient temperature.

Power consumption analysis

Largest single consumers are the container bridges which load and unload the container ships. Depending on the container weight, they take up to several MW during the lifting sequence. When lowering containers, the winch motors act as brakes and feed a large share of the energy that was consumed beforehand back into the grid. Due to their individual and not aligned operation mode, load peaks can add up drastically if, by coincidence, all bridges are lifting simultaneously. Conversely, in other moments loads caused by lifting and power outputs caused by lowering may level out themselves, or even cause a net feedback into the grid.

Refrigerated containers make up another very large group of consumers. Refrigerated containers are used in the global transport chain for storing chilled or frozen food. Each of these so-called “reefers” has an electrical on-board cooling unit. While on a ship, they are connected to the ship’s energy supply. At the terminal, they are plugged into the electrical grid. The investigated terminal has connection points for 2000 reefers. Depending on the amount and type of reefers connected, the load caused by reefers typically ranges from several hundred kW to around 2 MW.

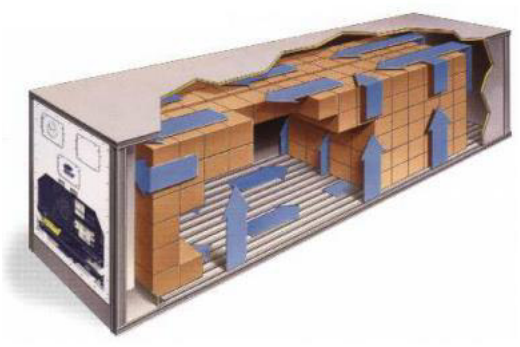
Quantification of the flexibility

Actively controlling the operation of container bridges in order to reduce load peaks was not desired by the project partner. Even though technically possible, the highly optimized and time-sensitive automatic unloading process is too complex and critical. An option would be the installation of a very short term storage buffer, which could absorb fed-back power from container lowering operations and provide power in the moment of several cranes lifting simultaneously.

Before further assessing options for short term buffers, it has to be investigated whether load peaks caused by container bridges are actually significant for the 15-min. load average, which is calculated to determine the peak load price component. It is well possible that load peaks are too short and that feed-back of other cranes partly compensates load peaks on a quarterly hour timescale. A detailed analysis of measurements will clarify whether and how a short-term buffer may contribute to even out the overall load profile. Viable technologies may include flywheels or super capacitors, which both store energy on a second to minute time scale and can rapidly absorb and deliver large

amounts of power. At any case, short term storage can only be used for load reduction purposes, not for load shifting over longer periods of time.

Reefer containers, on the other hand, can deliver flexibility over a larger timespan. They are very well insulated, as they have to maintain their temperature level for several hours even if not connected to the grid, for example during road transport or loading/unloading at the terminal. Especially reefers for deep-freezing allow a rather broad temperature range between e.g. -18°C and -22°C. Therefore, depending on their current temperature, the cooling devices of reefers could be switched off for a certain amount of time (several minutes to several hours) if a local smart grid has the necessity to reduce load. Conversely, they can be cooled down on purpose at times of high availability of electricity.



1 Schematic view of a reefer container. Source: GDV

The time scale of flexibility in the case of reefers lies between several minutes and several hours. The exact amount of flexibility provided by reefer containers at a terminal depends on various conditions: The total number of reefers connected, the percentage of deep-frozen reefers, their current temperature within the set boundaries and their remaining time at the terminal as well as outside temperature and the stored goods in the container. Therefore, it cannot be assumed that all reefers present at a terminal can deliver an identical amount of flexibility, i.e. that they can be switched off for several hours without exceeding temperature boundaries. This makes the calculation of available overall flexibility somewhat more complex.

Using historical reefer inventory data and monthly reefer consumption provided by the terminal, it was estimated that the reefers can perform a **load reduction** of around 1 kW/TEU on average. As the vast majority of reefers used are not **TEU (i.e. 20') but 40' containers**, flexible loads can be estimated at around 1.5 kW of reducible load per container.

This figure is somewhat lower than values for average reefer consumption usually found in literature that are in the area of 3-4 kW. One reason is that the figure above was calculated with a deep-frozen reefer share of 70% and an ambient temperature-dependent load of the reefers. As soon as more measurement data is available, figures will be validated.

The amount of **additional** load that can be activated is significantly higher. This is because usually more reefers are inactive than active at a given moment, therefore there are more reefers to be activated than deactivated. With an average simultaneity factor of around 0.2, 80% of the reefers are not running, which means that 3.2 kW/TEU would be available for a temporary increase of the load (or around 4 kW per 40' container). This is especially comprehensible taking into account that reefers

are designed to keep their temperature set-point at ambient temperatures of up to +50°C. Due to the temperate climate of northern Europe the cooling capacity of reefers is highly oversized which confers a benefit to the flexibility of reefers.

These figures give a rough estimation of the flexibility of reefers regarding load increase and reduction potentials but don't capture the flexibility in time. In order to also take this aspect into consideration a thermal model was built to depict the behavior of a large amount of cooled containers and to quantify the benefits for a concrete use case.

Technical aspects do not obstruct the use of reefers for load shifting purposes – the necessary communication protocols are implemented in the majority of reefers and solutions for terminals to control several hundred reefers are also on the market. For load shifting purposes, modifications of the software are necessary, but feasible.

The most interesting application in the Hamburg terminal would be to even out the load curve of the entire terminal in order to reach reductions in grid utilization costs. Also, a reefer-based load management system can be used to profit from a peak/off-peak tariff, by shifting as much load as possible to off-peak periods.

In the medium future, if renewable energy generation capacities are to be installed, a reefer-based load management system could help to increase the uptake of local RE generation: By pre-cooling the reefers at times of high renewable energy supply, hours with low RE supply can be bridged, thus maximizing the local consumption of RE production. At least in the case of wind energy, this leads to comparative cost advantages compared to feeding the wind energy into the grid and buying all consumed energy. This is because the total energy price most commercial customers pay is now higher than the feed-in tariff for wind energy, due to rising grid fees and lowered feed-in remunerations.

2.2.3 Conclusions

Possible revenues

The use of reefers as a shiftable load is technically viable. Economically, if a full exemption from grid usage fees can be reached, this would at the same time apply to all terminals operated by the company. Possible savings would amount to 4% of the company's total electricity costs, which is a significant amount in absolute terms. Necessary investments would amortize after far less than a year.
However, realization of this business case is subject to two conditions: Firstly, the shiftable load represented by reefers must be large enough to even out the load profile for the whole year – which, judging by first estimates is a very close call. Results of the currently ongoing measurements will tell whether it can be accomplished.
Secondly, the business case itself is in question: The grid fee exemptions are under revision by the EU, as they may represent hidden subsidies for the industry. If the exemptions are found to be against the EU regulations, companies may even have to repay grid fees for several years. A decision by the EU is expected for late 2013, and should bring clarity to this issue.

If an exemption from grid fees is not possible due to one of these factors, there are still profits achievable from a peak/off-peak tariff. These only apply for the actual loads from reefers that are shifted to off-peak hours. As explained above, real-world reefer flexibility is limited by several factors. It was therefore assumed that 10% of daytime reefer load can be shifted to off-peak times.

This would result in savings of 1% of electricity costs for reefers at that terminal, or 0.2% of total electricity costs.

Implementation

As mentioned before, measurement results are still pending – in case that both business cases are realistic, the company signaled interest for implementation. However, significant administrative issues would have to be cleared – for a discussion, see the Activity 3.7 report.

Scaling-up potential

The use of reefers as a source of flexibility is easily transferrable to other container terminals in the region and around the world. The Antwerp showcase has also analyzed this option and identified equally interesting potentials. The business cases that can be followed, however, largely depend on the local conditions. The substantial revenues which may be achievable at the Hamburg terminal through grid fee exemptions cannot be generalized. However, in other settings, there may be other promising business cases for a reefer-based load management system, e.g. through the integration of own RE production.
In Germany, only few container terminals with more than 1000 reefer connection points exist, with a sum of about 20.000 connection points.. Data on connections points at smaller terminals or other storage locations is not available.

Assuming that the average occupation is around 40% like in the Hamburg terminals, the total potential for load reduction on all large terminals could be estimated at 8 MW. Additional load that could be activated for a short time would be around 30 MW.

These are only rough estimations, and do not reflect the usually high variations in reefer numbers

2.3 Cold storage warehouses

2.3.1 Introduction

Refrigerated warehouses for storing frozen or cooled food are found at most commercial harbours around the world.
In most cases, they are cooled by vapor-compression refrigeration using electric compressors. Temperature within the warehouse is set according to the products stored, and controlled automatically by thermostats. Compressors also run automatically depending on the demand for coolant in the refrigeration system.
If cold storage warehouses are used for load shifting operations, the refrigeration system and thus the power consumption could be controlled in order to reach a certain increase or decrease in total load.
Due to the good insulation of cold storage warehouses and the large mass of cargo stored, temperatures within the warehouse will only rise slowly if compressor operation is interrupted.

2.3.2 Investigation summary

Available information

As mentioned above, three cold storage warehouses were analyzed in depth for e-harbours. Analysis was conducted by external consultants who have vast experiences in the sector of cold storage. The

scope of work included a field visit to each of the three warehouses and discussions with the operating staff in order to get first-hand data and information.
Permissible temperature boundaries for deep-frozen products lie between -18 °C to -23 °C. In case of exceeding the -18 °C boundary an alarm will be activated. Generally, customers claim for constant temperatures in order to avoid crystalline structural changes of food products. In two of the assessed warehouses are other temperature zones for specific products (+0.5 °C for fresh meat, - 24 °C for blood preservation and - 60 °C for tuna meat).
Heat losses result mainly from forklifts entering and leaving warehouses and outdated gates without appropriate heat insulation. Amount of heat input by stored products is difficult to predict. Operating staff did not make a statement about percentage of cargo exchange per day or time of exchange.
Load curves anyhow point to operating procedures during the day (see Power consumption analysis).
The analyzed cold storages differ in their installed compressor power, the existence of a central control for the cooling system as well as their operation strategy.

- Cold storage warehouse 1 is provided with a refrigeration plant controlled by programmable logic controller. Operators do not realize any load shifting activities.
- In cold storage warehouse 2, no DR activities were undertaken during the analyzed period. Following the showcase activities, the company decided to pursue some load shifting activities, see chapter on implementation below.
- The power control of the refrigeration plant in the third analyzed warehouse is realized by a factory master control system. DR activities comprising atypical grid utilization, peak load reduction and off-grid tariff optimization are realized by an external service provider.

Warehouse operators provide 15-min. load profiles of the years 2010 and 2011. This information was complemented with data on thermal behavior of cold storage warehouses derived from literature.

Power consumption analysis

Within a cold storage warehouse, compressors represent the largest electric consumers, even though ventilators, lighting etc. also have a certain share. Special warehouse equipment like vacuum packaging machines as well as electricity supply connections for truck container could also be relevant consumers. Total installed power in the analyzed warehouses was in the magnitude of 300-800 kW each.

Load profiles of the three analyzed cold storage warehouses reflect the above described operation strategies. In warehouse 1 load profile runs independently of the electricity tariffs. Often load demand even increases to a maximum level during load peaking hours and decreases during off-peak hours. This load profile clearly shows that no load shifting measures are implemented so far. The energy cost saving potential could be significant under consideration of operational procedures.
The load curves of warehouse 2 and 3 indicate efforts for active load shifting. During off-peak hours in the night, the load demand increases to a maximum level. At the beginning of the peak price period in the morning load is decreased to a low level and remain constant during the day. In the early afternoon hours load peaks can arise. In the late evening hours load increases again to a maximum level.
This load profile is often characteristic for cold storages operations. Cargo exchange occurs mainly during the night (22:00 h - 6:00 h). The maximum load is needed in order to keep priority temperature constant during loading and unloading goods. Unsold goods can be taken back. This process causes short-term load increases during the early afternoon hours.

Quantification of the flexibility

In order to facilitate calculations, it was assumed that the cold demand was rather constant throughout the day.
Thus, assuming that cold demand was linear to the power consumption, the average load over a 24h period was calculated in order to determine the baseline power demand.

In two of the assessed warehouses, active load shifting was already undertaken: These companies had a peak/off-peak tariff model, and shifted operation time of compressors towards the off-peak periods (usually nights and weekends). This was done by pre-cooling the warehouse to a certain extent in the early morning hours before the peak price period, and switching off compressors in the evening at the end of the peak price period.

For the warehouse where active load shifting was already undertaken, the integral between the measured load curve and the calculated baseline was considered as a minimum flexible potential, as it obviously can be exploited without compromising the warehouse temperature. This minimum flexibility was found to be between 15-30% of the daily consumption which can be reallocated freely within a day.
In this case, temperature varied by approx. 3.5 K. Additional flexible potential was then calculated by analyzing historical load curves and the correlating temperature curves.

Possible revenues were then calculated for different business cases. For this, the contracted consultancy used a simulation tool for virtual power plants that optimizes flexible consumers based on different business case scenarios.
The business cases that were assessed include several of the universal business cases listed in chapter 1.1 (for details on all business cases and their manifestation in Germany, see [EHAR 2013]).

Results on possible revenues are presented below.

2.3.3 Conclusions

Possible revenues

- **Business case 1 - contract optimization,** with a focus on off-grid tariff optimization, peak load reduction, and also the realization of what is called “atypical grid utilization” in Germany. This is a substantial discount on grid fees granted to a customer that has his periods of highest demand during certain pre-defined off-peak periods. Possible savings could be calculated very accurately.
  It resulted that the warehouse operators could save around 7% on total energy costs using this business case alone, equivalent to a low 5-figure sum in the analyzed cases. It has to be noted, however, that one of the assessed warehouses already made use of this business case in the assessed period using a basic timer mechanism – in this case, additional savings through an optimized control are much smaller.

- **Business case 2 - trade on the whole sale** market: This requires that the consumer buys energy directly on the spot market. In order to save energy costs, it is attempted to shift a large part of the energy consumption to times with low prices. As prices on the spot markets vary from hour to hour based on supply and demand, a price prognosis system is needed to predict the lowest prices within the current day. According to this prognosis, an operating schedule for the electrical consumers is developed automatically, and required that energy amounts are sourced on the market. In order to calculate possible revenues, the total energy costs during a year were calculated using real spot market price profiles from 2010 and the price prediction mechanism.

Due to the relatively small amount of flexible load that can be offered and the low price level for reserve capacity in the reference year, revenues were quite limited: It resulted that by smartly buying energy on the whole sale market, warehouse operators could save between 5 and 7% of annual energy costs.

- **Business case 4 - offer reserve capacity:** Reserve capacity provision in Germany is organized using an auctioning system, where flexible producers and consumers can offer positive or negative loads to the TSO in case of grid instabilities. For the provision of reserve capacity, a capacity price is paid, regardless of whether the flexible load potential is actually called upon. If the provider of reserve capacity actually receives a call to reduce or increase his load, an additional remuneration is paid. Prices for different types of reserve capacity vary substantially (positive vs. negative, primary/secondary/tertiary reserve capacity), also over time. For the calculation of possible revenues, historic data of 2010 was used.
  Due to the relatively small amount of flexible load that can be offered and the low price level for reserve capacity in the reference year, revenues are quite limited and amount to less than 1% of annual energy costs.

- **Combining several business cases,** as the e-harbours team advocates, yields greater revenues: Especially the combination of contract optimization/atypical grid utilization and the direct sourcing of energy on the wholesale market is promising: Revenues of both business cases add up almost completely, meaning that they are largely compatible, and do not obstruct each other much. This is logical, since time slices that count for reaching the status of “atypical grid utilization” mostly coincide with periods of low whole sale market prices (e.g. during the night).

Implementation

Conclusions regarding the implementation of smart energy solutions differ for the three examined warehouses:

- In the first warehouse, which does not have a central control infrastructure, implementation costs for a central control system would be too high compared to the expected savings. This is aggravated by the fact that the warehouse complex consists of several, separated units, which at the moment operate technically independent from each other. Implementation of a smart system is only thinkable if the warehouse is technically updated and renovated in the future.

- The second warehouse was already interested in undertaking DR measures at the time of the cooperation. The consultant contracted by the e-harbours team already cooperated with the operator on a larger scale and also had analysed other warehouses run by the operator. For the Hamburg warehouse, different options were discussed involving different levels of “smart” operation. In this process, the operator decided against a full retrofit with a central, automatized control system. Instead, only the business case involving atypical grid utilization was implemented, using a basic, semi-manual control mechanism:
  A peak-load management system was installed to reduce load peaks during peak times. Additionally, a timer-based system was installed to adapt compressor operation to the typical daily energy tariff variation. Timers are set manually by the operating staff based on temperature read-outs. This solution has the advantage of very limited investment costs. Possible additional savings from a smart control system that could follow more business cases were not considered high enough by the warehouse operators in the face of higher investment costs.

However, in a newly built warehouse by the same company in another German city, an intelligent system was installed in cooperation with the consultant. As part of a large-scale research project, it now takes part in a local VPP. Realized savings through optimized spot-marked procurement are in the range of 6-8% and confirm the modelling results for the Hamburg warehouses [ETEL 2012].

- In the warehouse that already undertook advanced load shifting, extra savings through a smarter control system and an optimized use of flexibility would be around 5%. The results were forwarded to the external service provider responsible for energy procurement and demand response. A feed-back whether operation could be improved has not yet been provided.

A closer examination of organisational and administrative barriers in this context can be found in the Activity 3.7 report.

Scaling-up potential

Cold storage houses are a classic example of potentially flexible consumers, and therefore well researched.
A study prepared for e-harbours calculated a total of over 270 MW of installed capacity in large cold storage warehouses in Germany. The average overall load caused by these is estimated to be around 50% of the installed capacity, or 140 MW.
If all of these warehouses were flexibilized, the overall load could be regulated between a minimum of 46 MW and a maximum of 250 MW over a short period of time [LANG 2011].

However, it has to be considered that the economic potential is considerably smaller, since only larger facilities with a central control system can be used with reasonable efforts.

3 Overall conclusions

3.1 Summary of the individual results (see 2.1.3 and 2.2.3, etc)

- The chemical production company offers very limited accessible potentials for smart solutions on the demand side. However, through the recent construction of a gas-fired CHP with a large capacity, new and very attractive potentials arise: By switching off the CHP on demand, negative reserve capacity can be provided (compare universal business case 4). This involves virtually no additional investments, and yields profits in the magnitude of 3% of total electricity costs. Furthermore, by installing an electric heater to provide heat when the CHP is switched off, the amount of negative capacity can be doubled, also doubling benefits with moderate investments that amortize after approx. 2 years.

- The container terminal is a huge consumer, but flexible potentials are limited. Reefer containers are the most potent source of flexibility, but the magnitude of loads is rather limited compared to the overall consumption at the terminal. However, due to the German grid fee regulations, even this moderate amount of flexibility could be sufficient to achieve a complete exemption from grid usage fees. In this case, savings would be 4% of total energy costs, a huge sum due to the high overall energy bill enormous , but the future of this business case is uncertain. At any case, small savings could be realized by optimizing reefer consumption towards a peak/off-peak tariff.

- Cold storage warehouses could save over 10% of energy costs by combining business cases 1 and 2. In warehouses where load shifting activities were already implemented, savings will be lower. Implementation costs vary depending on technical status quo of the warehouse. In general, companies are reluctant to pursue business cases, mainly due to high investment costs and/or administrative overheads.

3.2 General Overall Conclusions

As a general result of the assessed case studies in the port of Hamburg it can be derived that for every single case an individual analysis of flexible potentials and their trading options is necessary. It became evident that manifold approaches for smart energy solutions may exist, dependent on the consumers and generation capacities present. Flexibility concepts may involve load management, demand-based electricity generation by renewable energy sources, flexible conventional energy production and storage concepts.

Regarding the **six universal business cases** mentioned in chapter 1.1, essentially only business case 1 (contract optimization), 2 (trading on wholesale market) and 4 (reserve capacity) have proven relevant in the Hamburg showcase.

In the case of **contract optimization**, both grid fees and commodity energy prices may be reduced, of which grid fees usually have a larger reduction potential. This is related to various exemptions and reductions that grid regulations foresee for consumers whose consumption characteristics meet certain requirements (steady level of consumption, or consumption mainly during off-grid periods). The future development of this aspect, however, is uncertain: Firstly, grid utilization costs and other fees will continue to increase in the near and medium future. This is due to a growing amount of subsidized renewable energy and subsequent costs for grid extension, which are both levied on the energy consumers.

Secondly, exemptions from grid utilization costs and other fees are under investigation by the EU, as they are suspected to represent an unlawful subsidy of the national industry.

Wholesale market energy procurement is, in principle, feasible for all larger consumers. Here, flexibility is used to benefit from price variations over the course of the day. However, two recent trends in the German energy market are weakening this business case:
The first one is a general decline of electricity prices. This is due to the growing amount of subsidized RE production which is brought on the market at very low prices. So far, price-reducing effects were only notable on short-term marketplaces. Recent publications indicate that from 2013 on, companies with long-term delivery contracts will also profit from lower prices [BEE 2013]. Accordingly, prices for base load delivery at the European Energy Exchange will decrease by about 24 % in 2014 against the previous year. Due to this, spot market procurement becomes less attractive compared to long term contracts, and also the general pressure from energy costs declines.
The second trend is even more relevant for smart energy solutions: The typical price spread between night hours (low prices) and midday (high prices) has decreased drastically. This is due to a rapidly growing amount of PV production, which has its peak output at noon, just when demand is also high. A decreasing price spread in turn leads to smaller benefits from “traditional” load-shifting towards typical off-peak periods. In general, price variations over the day tend to be less predictable. Short-termed price spikes in both directions may occur due to the intermittent RE feed-in.
In the light of these developments, the business case requires a good price forecasting system and flexible potentials that can be dispatched for shorter periods and with more liberties. As this tends to make implementation more difficult, companies may be well advised to contract an external service provider.

Reserve capacity provision is a relatively new business option for flexible consumers. Access requirements to these markets have been somewhat lowered over the last years, and demand response aggregators have entered the market, integrating flexible potentials into reserve capacity pools. However, still a substantial amount of flexible load is needed to create significant revenues – pool operators have stated a minimum of 500 kW, but profits only become relevant when loads of one or more MW can be connected (above 5 MW, also a direct participation in the reserve capacity market is possible).
This is due to an on-going situation of relatively low prices at the reserve capacity markets. Especially for positive reserve capacity (i.e. provision of power, respectively reduction of consumption if dispatched), revenues are extremely low, due to large overcapacities on the production side.
Things become more interesting if consumers or producers are able to provide the requested load variation within seconds instead of minutes: In this case, they are able to participate in the secondary reserve capacity market, which offers 3-4 times higher revenues per MW (see table below).

	Positive (=less consumption)	Negative (=more consumption)
Tertiary reserve	5.381	26.384
Secondary reserve	21.754	92.718

Average capacity prices in EUR/MW/year for different types of reserve capacity
Source: [CLENS 2013]

Synopsis

It can be concluded that at the moment valid business cases manifest merely in particular cases, due to the price conditions for electricity and grid stabilising operations at present. Additionally, it became clear that energy costs often range in the single-digit percentile of production costs (except

in the energy-intensive industries). High energy costs are not as relevant as usually perceived; hence, there is often no cost-related pressure to implement energy saving measures in general, or smart energy solutions in particular.
Technically, the investigated smart energy solutions are ready to be implemented. Concerns about operational security did not play a major role in the showcase discussions. What hinders implementation are the costs for control infrastructure and the administrative overhead in the context of often limited revenues.

However, interviewed experts predict an increase of electricity prices due to shut-downs of many unprofitable base load power plants in the future. This could also lead to a higher demand for flexibility and increasing prices for grid stabilizing services within the next 10 years.

4 Lessons learned

4.1 Technical issues

- The cold storage warehouse showcase, as well as the chemical factory, makes clear that an existing central control system is crucial when trying to make use of flexible consumers. If, like in one of the analysed warehouses, devices are even controlled manually, implementation costs for a fully automatized system are likely very high related to expected revenues.

- The terminal showcase clearly showed that even large companies often have very little knowledge about details of energy consumption at their facilities. This, in turn, is a good door-opener for the introduction of smart energy solutions – sometimes, the company's interest in a flexibility assessment may be more of a general nature, so as to learn more about the status quo. If interesting potentials for smart solutions are then found, the company will be more likely to pay attention.

4.2 Economic issues

- Experiences from the showcase clearly show that economic efficiency is the main decision criterion for investments. Companies claim for short repayment periods (mainly under three years), independently of whether investments concern production or energy generation plants. This is a setback for business cases that are economically viable in the long term, but require high up-front investments.

- Another lesson is that not only the relative savings are decisive, but also the absolute amount of saved energy costs: In the case of the terminal operator, savings in the magnitude of around 5% amount to a much higher sum than in case of the cold storages, thus making a realization a lot more interesting. This is because implementation of many business cases requires a certain administrative overhead in form of staff hours, legal agreements etc. regardless of the amount of savings at stake.

- A general message was that the magnitude of annual savings in the 5-digit range is not enough to justify implementation, if it implies that an employee has to invest considerable amounts of time.

4.3 Ideas for further investigation

- The future challenge will be to better involve flexible consumers and decentralized producers in the electricity market. Therefore a modification, if not a complete redesign of the current market structure is necessary. This involves measures like opening trading markets for smaller production facilities, providing flexible demand-based electricity tariffs, creating incentives for power-based operation of CHPs (for more information see Del. 3.7).

- The concept of using electric heaters to substitute CHP or gas boilers in times of a power surplus in the grid is appealing. This concept called “power-to-heat” or “power-to-saved-gas” has received increased attention recently. A wide field for further investigation is the practical application and process integration of this concept. Developing an easy to use calculation tool to quickly estimate investment costs and expectable revenues could help to find potential applications.

- A very interesting and relevant field for investigation is the use of refrigerated containers, or reefers, for load shifting operations. The technical basis to externally control reefer power consumptions exist - but their integration into an automatic load management and planning system, or even a terminal-wide smart grid is a challenging task. This would include research and development on the hardware and software side, but also the development of a load forecasting model based on logistic data.

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e-harbours

WP 3.5 Application of Smart Energy Networks

Technical and Economic Analysis
Summary results of showcase City of Malmo

Authors: City of Malmö

Release date: 2013-11-25 (final)

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

1.1 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 both technical/economical and organisational/legislative conditions is crucial.

The e-harbours report 3.7 focuses on the *organizational and legislative aspects* of smart energy solutions. A long list of general barriers has already been composed (deliverable 3.3).
The report 3.7 addresses the analysis on a local basis (country/city/harbour), where the smart energy solutions are hampered.

This e-harbours report 3.5 focuses on the *technical and economical aspects* of smart energy solutions. The scope of WP3.5 is the translation of the 6 universal business cases (e-harbours report WP3.4) on the level of every showcase. It gives an overview of the potential for the exploitation within the existing local (national) rules and regulations.

This document summarizes the results for each of the showcases in the Northern Harbour.

Universal business cases: 6 possibilities defined

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 economic potential of the flexibility, offered by these devices, installations and/or companies is estimated in the WP3.4. WP3.4 summarizes the following cases:

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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 your context.

1.2 The strategy in case study Northern Harbour

Identification

For identifying the flexibility in the Northern harbour a mapping of the energy flows, including transports and waste, of the largest business operating in the Northern harbour was made. These businesses were interviewed and results put together in a report. The results were also presented at a workshop with all stakeholders in the Northern harbour area and the City of Malmö.
The following companies have been included in the case:

Energy actors and users: Cementa, EON Öresundsverket, EON Flinträннan, Finnlines, HJ Hansen, IL Recycling, Lantmännen Cerealia, Lantmännen Lantbruk, Norcarb, OKQ8, Ragnsells, Scandinavian Tank Storage, Stena Malmö, Stena Verkö, Sysav, Vindkraft Boel, VA Syd Sjölundaverket.

Energy producers: EON Öresundsverket, EON Flinträннan, Norcarb, Sysav, Vindkraftverk BOEL, VA syd Sjölundaverket.

Quantification

The flexibility is based on estimations. It is based on the actual energy production today and an estimation of the future potential energy savings and the capacity for increasing electricity production.

Valorisation

The value of the flexibility in the Northern Harbour consists in shifting natural gas to renewables into the district heating grid. In this way, the renewable share for the district heating in Malmö will go from 0 to 23%.

Exploitation

Up-scaling: No up-scaling scenario is foreseen since EON:s district heating grid is the only one supplying the city with district heat.

Introduction renewable: The renewable sources that will be introduced are wood-based incineration.

1.3 Scope of the e-harbours case study Northern Harbour

The deliverables of this case study are:

- The report ”Studie om industriell samverkan i Norra hamnen” (EN: Study on industrial collaboration in the Northern harbour), City of Malmö, Sweden, published by City of Malmö.
- The report “Utveckling av industrisamverkan i Norra hamnen, Malmö - sammanställning av arbete, data och resultat under 2012” (EN: Development of industrial collaboration in the Northern Harbour, Malmö – compilation of work, data and results 2012)”, published by the City of Malmö.

2 RESULTS

2.1 Northern harbour

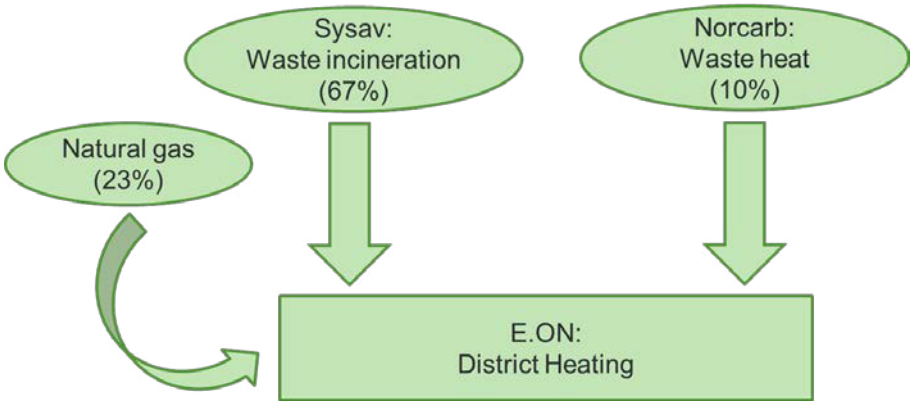
2.1.1 Introduction

The Northern harbour is the node for energy production for City of Malmö and the region of Skåne. EON and Sysav are the large producers of electricity, heat and biogas, which is distributed to the harbour and the city net for district heating, electricity and gas. The harbour area is 230 ha and now locates about 85 companies and is undergoing an expansion of another 450 ha.

The challenge for the City of Malmö and the region as a whole is that there is a lack of electricity production while there is an excess of heat, and that the energy mix is mainly based on conventional energy carriers. But, there exists a big potential in better matching production and demand, reusing excess heat and making capacity available for electricity production, as well as increasing the share of renewables of the energy mix.

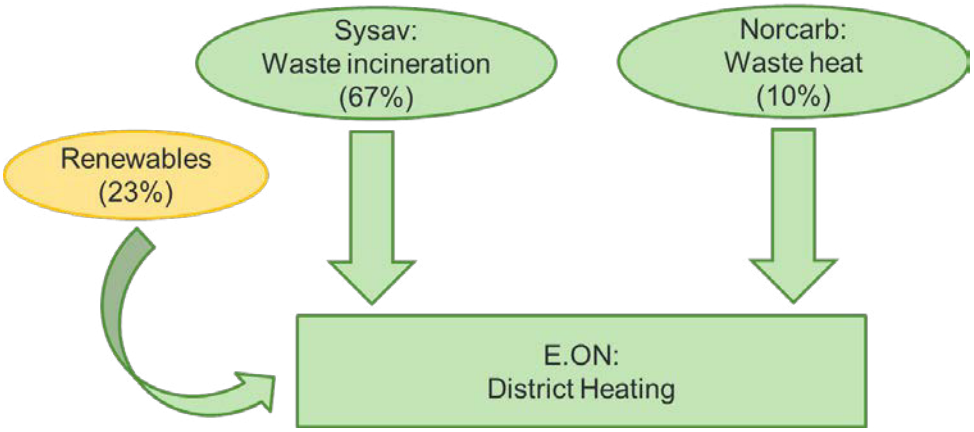
The scope of this case is to show how collaboration between companies in the Northern harbour and the City of Malmö can generate increased reuse of excess energy, capacity for electricity production and a greener district heating. The method is based on investigations and collaboration between the City of Malmö and companies in the Northern harbour, such as E.ON (energy producer and owner of the district heating grid), SYSAV (energy producer of district heat and electricity) and Norcarb (industry and producer of excess heat).

The first step in this cooperation is illustrated in the picture below.



The excess heat from Sysav and Norcarbs plants is transferred into E.ONs district heating grid. Sysavs part is 67%, Norcarbs part is 10% and the remaining part (23%) consist of natural gas from EON (Öresundsverket).

The **n**ext step in this cooperation is illustrated in the picture below:



The part of natural gas is supposed to be switched to renewable energy sources. This part is supposed to come from wood-based incineration.

A part from this, it will also be investigated how the heat generation from SYSAV and Norcarb can be made even more efficient. For example, SYSAV wants to invest in an accumulation tank to save heat during the day and use it during the night.

2.1.2 Investigation summary

Available information

The information available is energy production, energy use, transports and waste, from the different business in the Northern harbour, in terms of electricity, heat, steam, gas, oil, fuel. The share of renewable versus conventional heat production has not been distinguished.

Available data comes from the reports that have been written about the Northern harbour. The following are the figures that concern the show case in the Northern harbour:

EON Öresundsverket: 1 TWh heat per year to the district heat grid of Malmö (natural gas incineration)
Norcarb: 81 GWh heat per year to the district heat grid of Malmö (oil incineration)
Sysav: 1400 GWH heat from per year to the district heat grid of Malmö (waste incineration)

Power consumption analysis

Energy used:
Electricity: 148 GWh
Heat: 13 GWh

Energy produced:
Electricity: 3 247 GWh
Heat: 2670 GWh

Quantification of the flexibility

Since the tariffs for district heating are the same before and after the intervention, the flexibility is 0%.

Upscaling scenarios region/country

If more excess heat producing companies get connected to the district heating grid, the grid can be further developed in the region and provide more users with heat.

3 Overall Conclusions

3.2 General Overall Conclusions

The overall conclusions of the show case are the following:

- The flexibility of the case study is 0%, due to the fact that the tariffs don't change.
- The grid can be further developed in the region if more excess heat is transferred into the grid.

4 Lessons learned

4.1 Technical issues

One technical issue found is that there is actually more excess heat available for the district heating grid than used. This is because the infrastructure needed to connect to the grid is missing because of lack of incentives.

4.2 Economic issues

One economic issue found is the fact that the show case contributes to more renewables in the district heating grid but still doesn't lower the costs for the users.

4.3 Ideas for further investigation

Develop the efficiency of SYSAVS waste incineration and Norcarbs excess heat production.

5 References

[1] The report "Development of industrial cooperation in the Northern Harbour, Malmö"

e-harbours

WP 3.5 Application of Smart Energy Networks

Technical and Economic Analysis
Summary results of showcase City of Malmö

Author(s) : City of Malmö,
Release date : 2013-09-30 (draft)

Photo: Your location

The Interreg IVB North Sea Region Programme
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This document summarizes the results for each of the showcases in ...*enter your text here*

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6. 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 your context.

1.2 The strategy in showcase City of Malmö: Smart Homes

Identification
The strategy applicable to the show case is: *1. 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.*

The flexibility consists in shifting energy consumption to cheaper off-peak tariff hours and using renewable energy directly connected to the apartments: solar collectors for heating and hot water, PVCs and wind mill for electricity.

Smart homes residents have the flexibility to adapt the energy use on a 24 hours basis. Each day, residents receive on their app the electricity price for each hour during the upcoming 24 hours period (via Nord Pool spot). Users can then choose which appliances to be run during that period using the app. They can for example choose to charge the electric car, run the dish washer or the tumble drier during off peak hours. The app gives a very clear picture of the energy use per each appliance at home: the dish washer, the tumble drier, the electric vehicle etc. The residents can make a prognosis of the energy invoice and elaborate on how their energy consumption pattern will affect the invoice. All data is generated via and can be withdrawn from the app.

The flexibility has been identified by collecting data from interviews with the energy company EON, one apartment owner and general statistics on energy use and energy rates. The quantification of the flexibility is only estimation, since real data will be available first later this year.

Quantification
The flexibility is estimated for one apartment and aggregated to all the seven apartments in Smart homes. It is based on the following assumptions:

- That dishwasher, tumble drier, washing machine and charging electric car are made during off peak hours.
- That all apartments would make use of the energy from wind, solar collectors and PVCs that are installed at the Smart homes, which will reduce the energy costs since the renewable energy goes straight into the apartments.
- That the household appliances in the apartments are the most energy efficient on the market.

Valorisation
The value of the flexibility in Smart homes consists in shifting certain energy use to off peak hours. A household may choose to run for example the washing machine or dish washer during the night, when the electricity rate is lower, instead of during the day.

Exploitation
For the exploitation, a presumption has been made that the flexibility can be scaled up to all the new build apartments in the City of Malmö.

1.3 Scope of the e-harbours showcase in Malmo

The deliverables of the showcase are:

- Smart system with 100 control points for energy use and temperature in each apartment.
- Software consisting of an app for monitoring and steering energy use.

2 RESULTS

2.1 Case study Smart Homes

2.1.1 Introduction

Smart homes consist of seven smartly designed rental apartments in the residence area Western Harbour in Malmö, owned and managed by the energy company E.ON.

Different energy systems for electricity, heating and hot water are tested in the apartments: district heating, air/water-heat pump, gas and solar collectors. A hundred measuring points are installed in each apartment and residents can follow and monitor the energy use via an app on a tablet or smart phone.

Part of the energy is produced locally: solar collectors produce heating and hot water, PVCs and windmill produce electricity. The grid electricity has a fully variable price connected to the Nord pool spot intraday market.

Each apartment also has a vehicle included in the contract. In total there are five electric cars, one gas driven car, one electric vespa, seven electric bikes.

Smart homes focus on the user perspective:

- Visualisation – all energy use is measured and visualized
- Monitoring – all energy use can be monitored by the user
- Price model – the price model should be easy to understand.

2.1.2 Investigation summary.

Available information

Up to date there is almost no information available on the Smart homes. The reason is that the installations of all meters and the system has been delayed. But, from the 17th of September the total measurement system is running. The first evaluation has will give some results by the end of October this year.

Data has therefor been based on estimations on the following.

- Standard household energy use for heating and electricity – kWh and costs
- PVCs – kWh and investment costs
- Solar collectors – kWh

- Windmill – kWh

Data has been made available from EON on the investment and running costs for the following:
- PVCs

Power consumption analysis
Interviews with Smart homes owner indicate that there is a shift of energy use from daytime to night time, when energy price is lower. The dish washer, tumble dryer, washing machine are run during night shift, and electric car is charged in the night.

Household electricity kWh/yr	
Dish washer	300
Tumble drier	180
Washing machine	155
Electric car	750
Total	**1385**

Our estimation on the electrical car is based on that it consumes 1 kWh per Swedish mile (10 km). The average car in Sweden drives 1218 Swedish miles per year, but we decided to use a slightly lower number in our calculations since the residents don't use the car on an everyday basis.

Quantification of flexibility
The shift of energy and use of renewable energy is estimated to generate a flexibility for all the seven apartments of around 44 462 kWh, which corresponds to 33 483 Euro. This calculation is based on the difference between a standard apartment and the minimum tariff during a day for the show case. If the maximum tariff during the day is used, the corresponding figure will be 31 663 Euro.

Upscaling scenarios region/country
Scaling up the above described flexibility could contribute to reaching the energy and climate targets of the City of Malmö: 100 % renewable energy in 2030, reduction of energy use by 20 % per person 2020 and another 20 % by 2030.

If the strategy is applied in all new built apartments in Malmö, with the assumption that 10 000 new apartments will be built till 2030, the energy (electricity and heating) reduction potential would be 63 MWh per year and the savings on their energy bill would be 5,7 million Euros per year.

3 Conclusions

3.2 General Overall Conclusions

The overall conclusions of the show case are the following:
- The flexibility results in potential of 82% savings on the annual total energy bill compared to normal tariff and exploiting flexibility.
- The up scaling consequences on a local, cluster and regional level could contribute to reaching the energy and climate targets of the City of Malmö.

4 Lessons learned

4.1 Technical issues

- A smart charging function, that made it possible to charge the electrical car during the night when the electricity price was lower and use that electricity during the day when the price was higher, was initially planned to be installed in one of the vehicles. This could have contributed to an annual saving of 6-7000 SEK. However, this smart charging function was not available on the market. For this reason, an electric power station with some smart charging functions will be installed instead.
- The software is developed for Apple's products, which has caused problems for Android users.
- Problems when integrating several sensors and computers in the apartments

4.2 Economic issues

The value of the flexibility for a household economy is not very high, since there's not a very big difference in the rates between peak and off peak hours. There is little incentive to use the function. This is since the flexibility mainly is a result from the usage of very energy efficient household appliances and the usage of renewable energy from wind, solar collectors and PVC.

4.3 Ideas for further investigation

The ideas for further investigation are connected to the technical and economic issues:

1) Keep searching for a smart charging function for electrical vehicles.
2) Develop software for Android in order to make the service available for Android users and not only the ones using iPhone/iPad.
3) Find other incentives for the managing system than the economic ones. The managing system could for example show the environmental benefits of controlling the electricity consumption in the home.

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WP 3.5 Application of Smart Energy Networks

Technical and Economic Analysis
Summary results of Energy Management in the Fraserburgh area

Alan Owen, Leontine Kansongue, Ebun Akinsete, Simon Burnett and Andy Grinnall

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The report 3.7 addresses the analysis on a local basis (country/city/harbour), where the smart energy solutions are hampered.

This e-harbours report 3.5 focuses on the *technical and economical aspects* of smart energy solutions. The scope of WP3.5 is the translation of the 6 universal business cases (e-harbours report WP3.4) on the level of every showcase. It gives an overview of the potential for the exploitation within the existing local (national) rules and regulations.

This document summarizes the results for each of the showcases in the Fraserburgh area.

Universal business cases: 6 possibilities defined

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:

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

1.2 Energy Management in the Fraserburgh Area

The strategy adopted within the Fraserburgh area centres around local energy system management (universal business case 5).

The first showcase explores the management of the system by feeding in renewable energy sources into the grid to supplement supply and use/ implementation of heat recovery system (from refrigerators) for space heating. This is supported by a feasibility study on the viability of a wind turbine is in progress as well as monitoring energy usage.

The second showcase expands the view of local energy systems to consider embedded energy flows within local produce. It conducts a life cycle analysis of fish produce from the Fraserburgh area, and examines the potential energy reductions that could be made by encouraging more responsible consumer behaviour through the use of an energy product label.

Identification of flexibility

Flexibility within the showcases is presented as a factor of energy reduction attributed to the interventions; specific reductions in energy usage by the Fraserburgh Ice factory, as well as Net energy reductions in fish production in the Fraserburgh area.

Quantification of the flexibility

Flexibility is measured in terms of KWh of energy.

Valorisation of the flexibility

Using the European Commission definition of valorisation[1], flexibility in terms of potential energy reductions achieved as a result of the showcases may be valorised by promoting awareness among business owners of the potential economic benefits associated with; a) increased use of renewable energy and b) production of less energy intensive goods.

Exploitation of the flexibility

Primary exploitation of the flexibility is in the potential to realise economic benefits for stakeholders in the form of potential cost savings on energy bills and potential increase in revenue from sales boosted by production of an ethically labelled good.

[1] *"the process of disseminating and exploiting project outcomes to meet user needs, with the ultimate aim of integrating and using them in training systems and practices at local, regional, national and European level." (EC,2006)*

1.3 Scope of the energy management exercise

The core aim of the energy management exercise in Fraserburgh was to examine the workings of the energy systems in the area; exploring the generation, use and flow of energy within this system. Thereby providing a basis for strands of activity which seek to address the sustainability of this energy system; either by grid management or life cycle analysis of embedded energy. The core areas of activity covered include:

- Modelling energy use with the aim of establishing the potential for promoting greater use of renewables, smart grids and virtual power plants, electric vehicles and measures to improve energy efficiency

- Viability of production and use of renewable energy in harbour cities from wind, solar PV, tide, waves and the reuse of industrial waste, heat or cooling available

- Attuning demand and supply of energy by flexible demand management, load shedding, energy labelling, intelligent storage

- Developing an energy labelling scheme for fish for use by domestic consumers

Researchers from RGU's Institute for Innovation, Design & Sustainability (IDEAS) and Institute for Management, Governance and Society Research (IMaGeS) worked in collaboration with the Fraserburgh Harbour Commissioners Office, local businesses, retailers, and industry bodies in order to conduct the above listed activities.

2 SUMMARY RESULTS

2.1 Monitoring energy usage and meteorological variables

2.1.1 Introduction

Aim:
The aim of this project was to monitor the energy usage and meteorological variables in small to medium sized harbour area with the intention of promoting the use of renewable energy to improve efficiency and encourage a more sustainable environment.

Objectives:

- Identify different types of energy usage.
- Identify available renewable energy resources.
- Monitor the use of energy and the availability of sources of renewable energy.
- To estimate the contributions of other system parameters using models developed from available data.
- Test model on data from another harbour
- Increase the production and use of renewable energy in harbour cities from wind, solar PV, tide, waves and the reuse of industrial waste, heat or cooling available
- Develop an analytical model that can be used to predict energy use in any small or medium harbour from limited data inputs
- Develop a measurement and data analysis strategy allowing small to medium sized harbours to prioritize their investment in renewable energy and smart grid systems
- Identify areas where improved metering or monitoring can improve or cut down energy usage

This showcase looked at two areas: first, the monitoring of energy usage for businesses operating around the harbour with the view of finding ways to cut down consumption and secondly, meteorological measurement to assess viability of a future wind turbine to supplement supply therefore leading to reduction in carbon emission.

During the first stage of the work, various meetings were held to identify the types of energy used by different stakeholders. This was then followed up by installation of instrumentations kits such as current monitoring tool. With the data gathered, strategies are being developed for use by harbour authorities and commercial businesses in the harbour area to reduce their carbon dioxide emissions, energy use and energy bills. These strategies will give information of the cost of implementing each measure and the savings that would be made once this is in place. The second part of the work involved the installation of a weather station to monitor meteorology availability with the ultimate aim of installing a wind turbine in future.

The study envisaged energy usage and the challenges faced by the industries within Fraserburgh harbour area to identify gaps and set recommendations that will help reduce energy bills and carbon emission therefore providing stakeholders with strategies for increasing their sustainability.

2.1.2 Investigation summary

The research done was based on two different aspects:

- Monitoring of energy usage
- Meteorological measurement

The monitoring energy usage stage involved a pre-study of the businesses to identify the different types of energy used, the equipment/machinery utilised and a field study of the business plant rooms to identify best energy monitoring equipment required to measure the power consumption of buildings and machinery. Utility bills were also gathered to assist in analysing the overall power consumption of the factories/businesses. Instrumentation tools such as pico-current monitoring kits and power quality analyser were used to measure the power consumed. These equipment were installed in various plant rooms to automatically record and download the energy used every 10min. The main objective of this was to help identify periods of high consumption to better understand the energy usage and find means to reduce this.

The second part of the work involved installing a weather station to monitor meteorological data. A mast was installed outside the harbour area with the aim of measuring the wind speed from two anemometers: one being 10meters and the other 20meters high. Davis weatherlink software was also installed to link davis weather station to a computer direct to a network set up in the harbour office. This allowed all logged weather data to be stored, viewed and analysed in considerable detail. The installed weatherlink software records data such as wind speed, temperature, wind direction, dew point and humidity. The recorded data were used for analyses to determine future viability of a wind turbine.

Available information

The information provided within this study is based on:

- Desktop study
- Interview notes with stakeholders
- Primary and secondary data collection from equipment such as data loggers(Pico current monitoring kits and Power quality analyzer; Davis weather station)
- Fieldwork notes
- Publications
- Electricity meters readings and utility bills

Power consumption analysis

The power consumption analysis was based on the energy usage in KWh to operate the business and machinery. Pico current monitoring kit and power quality analyser were installed to automatically download the current usage of the factories. These were measured in Amps and the power quality analyser measured the power in watt, the current in Amps, the phase angle, the reactive power in Var. The study evaluated the overall energy consumption based on the data acquired.

Quantification of the flexibility

Flexibility within this study is represented by the total reduction in energy used by the machines and the businesses in general. This is measured in KWh.

The study is still on-going therefore a complete quantification of the flexibility at this stage is not yet feasible. The flexibility reflects the potential net energy reduction in the harbour area as a result of feeding in renewable energy sources into the grid to supplement supply and use of heat recovery system (from refrigerators) for space heating.

2.1.3 Conclusions

The scope of the work done till date shows a constant power consumption profile by most businesses and flexibility at this stage is quite difficult to define but not impossible.

There is a potential of reducing the energy usage if renewable energy is fed into the grid system and measures are taken to make use of the heat recovered for space heating especially during the winter. Result at this stage might not be accurate, but there is a huge potential of reducing the amounts of energy used per KWh, therefore a reduction in utility bills as well as carbon dioxide emission.

It was identified during the study that most businesses make use of peak and off peak period meters where appropriate to cut down their energy bills but none of them considered the use of heat dissipated by refrigeration systems to warm their offices and this is wasted. The use of the dissipated heat to keep offices warm could save a lot of KWh of energy.

Another aspect of the study revealed that most businesses keen on reducing their expenditure on energy without recognising that the integration of renewable energy in their supply will accrue them lots of benefits.

Finally current government has the ambition to move towards a more sustainable environment thus commending the use of renewables to promote a friendlier environment.

2.2 Energy Label for Fish Products

2.2.1 Introduction

Aim:

To model the amount of energy consumed at different stages of the fish production process, with the view to developing and eco-label for fish products

Objectives:

- Energy modelling of the 'supply chain' for fish landed in Peterhead and /or Fraserburgh fish markets (energy consumed in catching, landing, logistical transportation, processing, packaging, etc) from sea to supermarket via different supply chains (local, national , international)
- Survey and focus group research on the information management aspects of the labelling system, the labelling architecture and how consumers read and respond to the labels
- Survey and focus group research on the consumer decision making process
- Identification and recruitment of a retail partner
- Development of appropriate energy labelling scheme for fish products landed in NE of Scotland, and information web portal for domestic consumers

This showcase involved research into the design of an energy label for fish that have been caught, processed, transported and sold using in the Fraserburgh area. The work which was a collaboration between two of the University's research institutes, the Institute for Innovation, Design & Sustainability (IDEAS) and the Institute for Management, Governance and Society Research (IMaGeS), incorporated energy life cycle analysis techniques as well as research into the design and use of food labels to explore the viability of an eco-label for fish products which displays the amount of energy used in catching, processing and transporting the product.

The development of eco-labels has arisen for a variety of reasons, relating to a number of environmental themes such as sustainability of resources (forests, water, and animals - including fish) greenhouse gases, environmental pollution, food and crop issues such as organic, food miles, and out of season provision. Trends such as 'green consumerism' highlight the fact that buyers are becoming increasingly conscious of the ethical credentials businesses they patronise; with sustainability and environmental impact of products featuring as a criteria for purchase (Young *et al,* 2010). It is expected that having a clearly visible label with information on the 'energy cost' of a product not only helps consumers make an informed decision but encourages more sustainable behaviour. With consumer spend as a driving force behaviour change among businesses can also be encouraged. Thus more businesses will be motivated to seek energy efficiencies within their supply chain so as to reduce the embedded energy in their products.

The showcase examines the flow of energy within the local system, and bridges the gap between the businesses (as the key energy users in the focus areas) and their consumers, with the overarching aim of reducing energy use within the system as a whole. While a number of labels which display information on CO2 emissions and ethical fishing practices currently exist, there are none which specifically address energy use in fish production.

2.2.2 Investigation summary.

The investigation presented two parallel strands of research:

- The production and use of eco-labels (led by IMaGeS)
- The life cycle assessment of energy use in fish production (led by IDEAS)

The core objectives of the first strand of research focusing on the label itself were to:

- present an overview of eco-labelling
- give examples of how labels are currently used
- present a standardisation regime applicable to the creation of eco-labels
- outline and illustrate possible label designs that may be appropriate for the fish energy label

The second strand of the investigation was focused on compiling the data required to populate the label. The main objectives of this strand were to:

- Identify possible methods of life cycle analysis
- Identify appropriate case study species
- Chart outline supply chain for selected species
- model the energy consumed along the 'supply chain' for fish landed in the Fraserburgh area
- Identify key issues relating to the study

Available information

Information utilised within the investigation was sourced from:

- Primary data from interviews with fishermen, local businesses, professional industry bodies
- Primary data from energy monitoring equipment
- Historic energy consumption from utility bills
- Fieldwork notes
- Existing literature
- Governmental and Nongovernmental Reports
- National and International Standards

Power consumption analysis

Power consumption analysis was considered in the context of total energy use in the production chain (from catching to distribution). A supply chain process chart was developed (see appendix 1) which formed the basis of the life cycle analysis. The analysis reviewed the total amount of energy input at each stage of the process to provide an overall figure in KWh. Based on data production data from local businesses a KWh/tonne figure was reached for both white fish (haddock) and pelagic fish (mackerel).

Quantification of the flexibility

Flexibility within this showcase is represented by the total reduction in energy used for fish production, and is measured in KWh.

While it is not possible to present a precise quantification of the flexibility at this stage due to the long term nature of this showcase, the flexibility reflects the potential net energy reduction in the harbour area as a result of businesses displaying the embedded energy of their products on the label. This will potentially motivate businesses to increase their energy efficiency during the fish production in order to gain a competitive advantage.

2.2.3 Conclusions

There is an opportunity here to address a gap in the scope covered by eco-labels currently in use. The current EU energy label covers the energy performance of electronic goods, and even with the likes John Lewis recently launching a trial of a life cycle based products for their most popular household appliances (Smithers, 2013), there is still no such equivalent for fish products.

The most widely used eco-label for the fish industry which is issued by the Marine Stewardship Council assesses the production chain of custody standard focusing on biodiversity and does not consider the energy input into the production process. This shortcoming was highlighted in a report by the Department for Environment, Food and Rural Affairs which stated that most environmental labelling schemes for food products were 'practice-based', thereby focusing on ethical issues in relation to the food production process; however there was a dearth of labels which adopted an 'outcomes-based' approach that would provide *"greater technical credibility to the label and enable consumers to better understand product-specific environmental impacts"* (Defra, 2010).

Flexibility in terms of energy savings offer an added financial incentive as cost savings. More organisations are considering the energy efficiency of their supply chain, with companies such as Unilever recording 10% reductions in their environmental footprint in 2 years, which in turn has translated into $250 in cost savings (Jerschefske, 2012).

Current views by the government suggest that labelling should be considered as part of a suite of government initiatives to address energy use and behaviour change. It is suggested that energy labelling efforts be coordinated and integrated into industrial schemes and governmental regulations both at national and international levels (Defra, 2010; FCRN, 2011).

3 Overall conclusions

Analyses of energy usage in Fraserburgh harbour focused on various businesses such as fish factories, ice factory and main harbour offices as a whole which included market around the harbour and all other branches operating under the auspices of the harbour. For most of these businesses, instrumentation kits were installed on their premises for energy measurement.

The study showed that further reduction in energy usage is attainable if renewables such as wind energy is used and heat recovery mechanisms are implemented. However means of motivating and incentivising lower energy usage still requires further investigation. The use of an energy label has been proposed by the government as a viable option which should be considered in conjunction with a suite of government initiatives.

4 Lessons learned

4.1 Technical issues

- Impact of external forces on data collection (e.g. adverse weather)
- Availability of commercially sensitive data
- Seasonal nature of the fishing industry
- Availability of viable data for all stages of the Life Cycle Analysis
- Technical fault and humans errors
- Operational fault
- Seasonal nature of the market
- Non uniformity in machines/equipment used such as difference in power cables requiring different types of instrumentations for energy measurement.

4.2 Economic issues

- Costs associated with data collection (particularly at the later stages of the life cycle analysis where paths become increasingly divergent)
- High cost of instrumentation used for data measurement
- Proximity of site to workers incurring travel expenses

4.3 Ideas for further investigation

- Consumer testing of the energy label
- Energy label for other products
- LCA considering the entire life cycle (through to use and disposal)
- Further study should consider the viability of marine energy(waves and tides)
- Consideration of waste recycle for bioenergy

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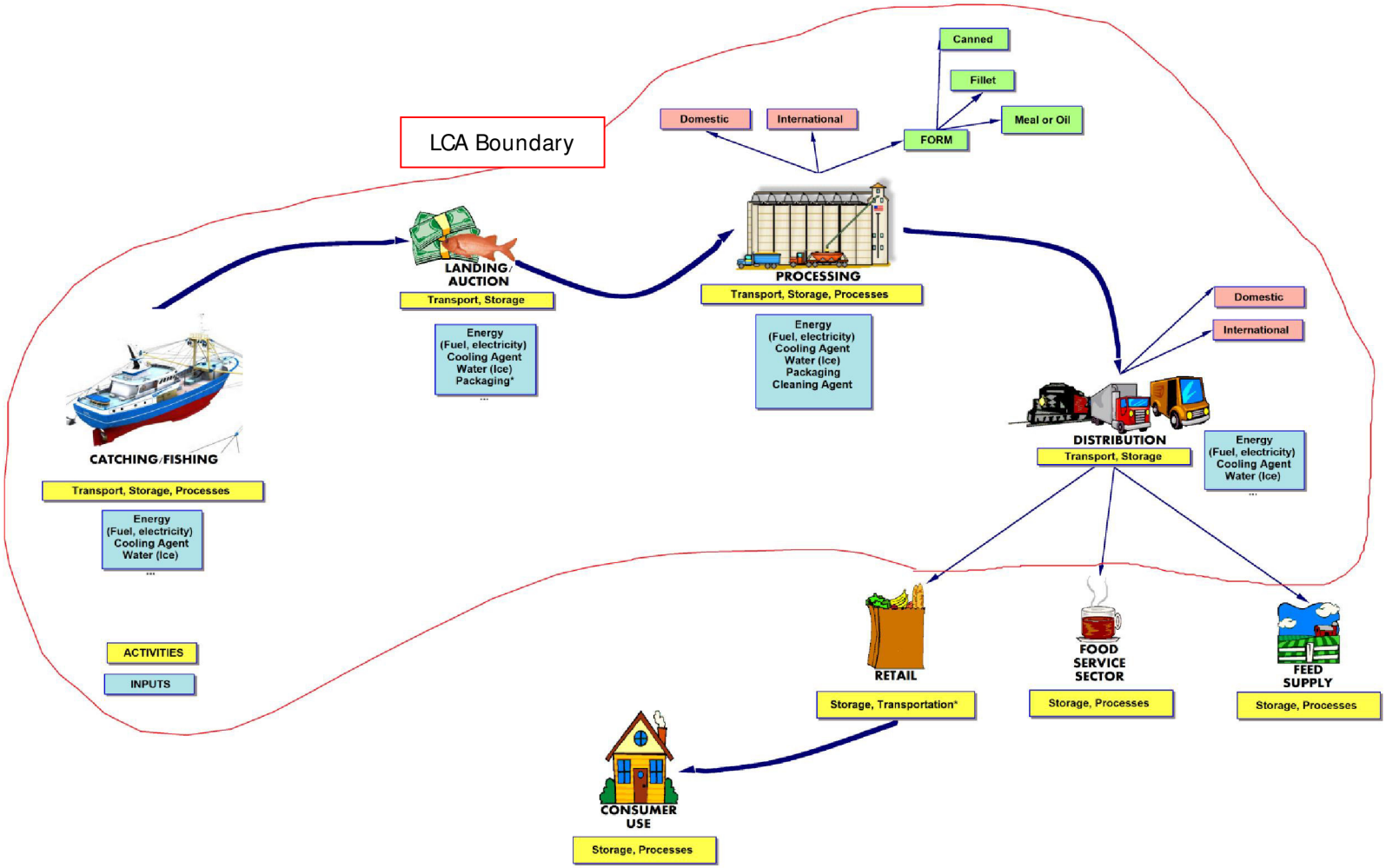
6 Appendix 1: Process Chart for Fish Production



'Process Chart for Fish Production' (UNEP, 2000; Thrane et al, 2009; BSI, 2012)

The Scalloway Showcase

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

ACKNOWLEDGEMENT

This report has been realised with the support and input of many experts. We thank all those who have provided input and contributions and helped to shape the document. We also tanks The Interreg IVB North Sea Region Program for supporting this project.

TABLE OF CONTENTS

INTRODUCTION

Harbours are widely recognised as an important, if not a key engine of any country's or island's economy. North Europe hosts some of the largest harbours in the world, which allows the supply of goods to countries and cities in and around the European Continent. At the same time, Europe as a whole, hosts thousands of small to medium harbours, which face similar challenges to their counterpart large scale harbour operations.

The North Sea based Harbour cities are subjected to an unprecedented level of difficulties arising from many different horizons including a record vessel traffic, rise in energy needs, sharp increase in energy costs and intense worldwide pressure on reduction in pollution and emissions. All of these pressures mean that harbours are now being targeted by many to find new and effective solutions to lead to better, more effective and sustainable harbours.

The objective of the Shetland's Scalloway Harbour showcase is unique as it will have a long lasting impact on the wider harbour community. This showcase intends to devise a better understanding of the operation of a small harbour setup and how this can lead to the introduction of novel energy policies across the North Sea Region (NSR). The ultimate goal of the Showcase is to devise, test and disseminate a universal harbour data monitoring strategy, which has been applied and tested in Scalloway Harbour. The aim being that, in the future, the findings can be applied to other harbours of similar size, but also large scale harbours at European level and beyond.

THE STRATEGY IN SCALLOWAY HARBOUR

Scalloway is an important fishing harbour situated on the west side of the Shetland Islands, in the United Kingdom. The relatively small size and the large variety of activities within the harbour area make this site a unique interesting showcase for the uptake of smart grid and renewable energy solutions into a harbour area.

Fishing harbours such as Scalloway have strong environmental impacts with high CO_2 emissions and fish waste. The energy demand is high due to the refrigeration and fish processing plants contained within the harbour area, along with transportation, heating systems and shore power for marine vessels whilst in the harbour. As such, a strategy was developed to identify to identify the highest energy consuming systems within the harbour and how to deal with these when faced with the need for reducing energy consumption.

AIMS AND OBJECTIVES

The aim of the Scalloway showcase is to improve the harbour sustainability, improving efficiency and facilitate the possibility for the implementation of renewables, smart grids and virtual power plants in the area.

This showcase presents a set of criteria to be used for the effective monitoring of energy consumption in small, medium and large scale harbours. It also supports harbour organisations to quantify their environmental impact within the harbour complex. The outcomes of the infield application of the universal strategy will allow the harbour community to analyse their energy consumption and behaviour. This will in turn lead to the development of new and effective energy management strategies to reduce harbours energy costs and become more competitive, locally, regionally, nationally and internationally.

Of importance, the monitoring strategy takes into account that the use of renewable energy within a harbour can lead to a potential unbalancing effect with the local electrical grid network, as the generation of renewable energy often does not match the local energy demand. Therefore, the strategy takes into account the concept of smart grid and Virtual Power Plant (VPP), and the need to introduce controllable loads (dumping loads, energy storage loads, etc.) that can be switched on and off as and when renewable energy is available, leading to an effective, efficient, clean balancing of the electrical grid[1].

The specifications for the data monitoring and analysis system are firmly related with the topology and nature of harbour activities, human habits and technical and economical requirements. These features can differ

[1] http://pureenergycentre.com/download/

significantly between small and medium sized harbours, so it is crucial to define and implement a universal strategy that can be extended and applied for different harbours sizes.

STRATEGY DEVELOPMENT

The strategy developed for Scalloway Harbour supports the identification of equipment that can be controlled using smart grid, the installation of VPP, the development of renewable energy in within a harbour set up and the reduction of CO2 emissions.

The overall aim of the Strategy is to develop a data logging methodology to reduce the cost of the assessment process (time, CAPEX, OPEX), making it more attractive technically and financially for future harbours. The strategy will also allow for modelling highly consuming equipment and devise a new harbour energy configuration, where Smart Grid, VPP, and Renewable Energy systems are used.

The Strategy is based on the following criteria:

- Identify potential Capital Expenditures (CAPEX) investment from stakeholders
- Shortlist high energy consumption processes
- Identification of willingness for change by stakeholders/users (buy in)
- Defining if there is a potential for high improvement by modifying the process
- Finding the areas where there is potential for implementing: Energy efficiency measures, Smart grid, Renewable energy, VPP.

From the above, a 10 points universal energy data logging strategy for Scalloway Harbour has been developed and is summarised below:

1. Site analysis of processes/equipment sizes and their locations.
2. Collection of energy bills, production figures, and analysis for each organisation.
3. Short listing energy intense equipment with an energy consumption footprint.
4. Identification of equipment that can be used in conjunction with smart grid, VPP, etc
5. Short listing equipment that have high positive improvement / impact on energy consumption if replaced
6. Assessment of willingness of stakeholders to invest into new equipment
7. Install monitoring equipment
8. Develop a model of the most energy intense equipment and generate a new energy configuration of the harbour.
9. Estimate contribution of Renewable energy, VPP, Smart grid
10. Training of staff on energy efficiency measures.

The first 6 points in the Scalloway Strategy aim to acquire knowledge on the Harbour activities; machineries used and identify the Energy consumption levels with associated CO2 emissions.

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This first 6 points assessment stage are optimised to reducing the cost of the second stage process monitoring (point 7 to 10), thereby making data logging more attractive for future harbours. In addition, the first stage is must be implemented with a view to reducing disruption to stakeholders activity and minimal interference with businesses. For this reason the initial site analysis is achieved by collecting Energy bills and internal records. This data are in sufficient number to shortlist the high consumption processes.

The rationale for choosing the energy bills method for creating an initial shortlist of energy data monitoring points is that they provide a good compromise between; (a) the impact of each energy process onto the cost of running the harbour business, (b) the possible integration with Smart Grid and Virtual Power Plant, (c) potential capital replacement and (d) cost reduction of the monitoring equipment. This method can therefore be directly applicable to any other harbours.

When the equipment consuming the most energy is defined, the equipment is assessed again with the following criteria:

- **Impact of each Process (%):** this represents the percentage of energy consumed by the process in relation to the overall harbour consumption. This information is achieved through historical energy consumption figures from monthly and/or quarterly utility bills.
- **Possible Load Smoothing:** this identifies if the process or consuming organisation can be utilised for load smoothing. This information is achieved by examining the consuming organisation or process in greater detail to ascertain if it could be used as a deferrable load.
- **Capital Replacement:** this identifies processes that can be replaced with an improved efficiency. It also checks the return on investment made through the acquisition of a new process. This information is gathered by speaking with the organisation to identify their ability to invest in new equipment and their willingness to upgrade their processes.

The integration of Smart Grid system and Virtual Power plants implies the possibility to control processes inside the harbour in order to provide a smoothing effect for the overall electrical energy consumption of the Harbour. The initial site analysis can provide the knowledge required to propose processes as possible candidate for the integration with Smart Grid and Virtual power plant. Process needs to be analysed in terms of organisation`s requirements, time of use and flexibility. Such processes could take the form of boiler tanks, fridges, freezers, heaters, etc.

Data loggers and monitoring equipment are then used to acquire the missing information and reduce some of the uncertainty acquired from energy bills and report.

Once the gathering of information is complete, it is possible to focus on the modelling activity for the most energy intense equipment and develop a reconfiguration of the harbour's energy system and profile by a better control of the energy intense equipment (with RE, Smart grid, VPP, etc).

The final outcome of the Strategy is to provide a series of recommendation to the end user with the result of the analysis and provide training and educational material for staff on energy efficiency measures.

RESULTS

As aforementioned, Scalloway Harbour is an important Scotland based fishing harbour situated on the west side of the Shetland Islands. It is the third largest harbour in the Shetlands.

The intensity and the large variety of activities in a relative small footprint make Scalloway Harbour a unique case study for investigating the energy issues encountered within a harbour setup through the development of an energy monitoring strategy.

As such, Scalloway Harbour was the ideal candidate showcase within the E-Harbours Project to assess and potentially improve the environmental and energetic condition of an entire harbour. All other showcases within the E-harbour focus on small areas of harbours due to their very large footprints.

INVESTIGATION SUMMARY

AVAILABLE INFORMATION

The information used for the analysis of Scalloway Harbour is derived from already available data from the Harbour organisation and from data collected through process monitoring. They are listed below:

- Data available from Harbour organizations:
  - Electricity bills, oils consumption records, production figures.
- Data available from site monitoring:
  - Data from installed sensors and dataloggers on site: Energy data, oil consumption, temperature and weather information.
  - Site visit and Stakeholders meeting for the acquisition of knowledge on activities and processes.
  - Questionnaire with stakeholders about flexibility of their activities, and ability on capital investment for hardware replacement.

POWER CONSUMPTION ANALYSIS

Despite its small size, counting a footprint of only 50,000 m2, it was found that Scalloway Harbour is an intensive energy consumer. Being a high energy consumer, the harbour related carbon emissions are, in turn, extremely high. To put this into context, the average yearly electricity consumption for Scalloway Harbour has been found to be 1.8 GWh/year. Heating fuel is another large energy source used within the harbour, with average annual energy consumption for heating oil typically around 643 MWh/year. As result, the overall CO2 emission for stationary energy consumption has been found to be 1350 t/year.

Scalloway harbour groups six private organisations and a harbour head office. The below figure, Figure 1, illustrates the percentage energy consumption for each organization operating in Scalloway harbour.

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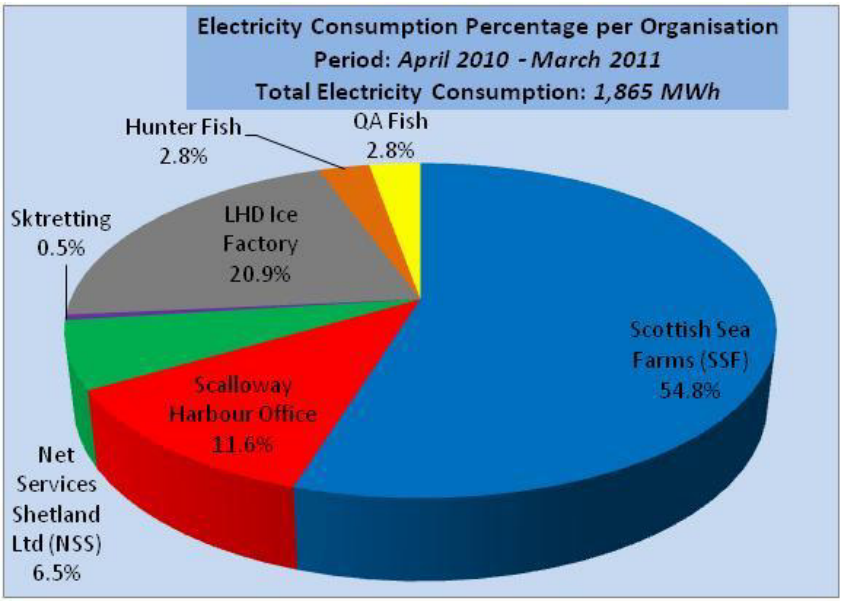

Figure 1: Percentage electricity consumption per Scalloway organisation

Scottish Sea Farms (SSF) is a fish processing company and it represents the biggest electricity consumer of Scalloway harbour. It is responsible for 54.8% of the overall harbour's consumption.

Scalloway Harbour office organisation represents only 11% of the total electricity consumption even if it has the largest facilities in the harbour. This is due to the limited use of heavy industrial activities.

LHD Ice factory is a small ice plant factory that uses Ice Making Equipment which are inherently high energy consuming devices. The produced ice is used in many harbour organisations and loaded in fish boats.

Net Services Shetland (NSS) is a Fishing Net repairing company. It appears to be a low energy consumer as Figure 1 takes into account only the consumed electricity. If we include the high oil consumption for net drying procedure, the overall energy consumption of NSS organisation will be higher. In fact if this is taken into account then NSS will become the second most consuming organisation of Scalloway harbour.

The other organisations can be considered relatively small users with electricity consumption lower than 3% of the entire harbour.

QUANTIFICATION OF THE FLEXIBILITY

Working activity within the Scalloway harbour is highly unpredictable and not constant all year round. The high dependence upon the fluctuation of landing fish to the market, the logistics constrains and in addition weather unpredictability makes it difficult to predict a steady operation of the Harbour activities.

By installing dataloggers on site for monitoring the energy consumption of the process it has

been possible to record the energy profile during the working days in the Harbour for the full year 2012.

It has been found that the working days are neither scheduled nor neatly distributed between the weeks. Due to the high dependence upon the fish landing market, the unpredictable arrival time of vessels at the harbour, the weather condition and logistic constrain within which the harbour operates, the working days are mainly dictated by external conditions and therefore are not flexible timewise.

Due these constrains, the flexibility on process and activity within each organisation is very limited. The adopted working policy for each organisation is to follow the demand that is generally dictated by external condition.

Even if there is a presence of Cold Stores and Ice plant that in theory could be used for flexible load for an intelligent demand site management, they are not suitable for flexible load, because of the limited capacity in relation to the harbour request.

For this reason the strategy has been focused on the following points:

- Energy efficiency measures
- Integration of Renewable energy
- Training and providing recommendation to the end user on renewable energy generation and energy savings measures.

QUANTIFICATION OF ENERGY EFFICIENCY MEASURES.

Even if the schedule of the working days is neither predictable nor flexible, by analysing the trend of power consumption for each month, it has been possible to define an energy routine and repetitive behaviour on how electricity is used during each working day. The profile of electricity used for each working day is mostly cyclical; therefore it has been possible to assess the energy efficiency on the process and activities within the harbour. This analysis has provided an understanding of what is the standard working day behaviour. It also supports the identification of where to focus the efforts in trying to reduce the energy consumption.

By analysing the average electrical power consumption of a typical working day, it is possible to identify the following recommendations:

1) **Reduction of Standby power.** At night periods, when there is no processing activity, there is still substantial energy consumption due to the Standby energy consumption of the processing plant. It is therefore recommended to reduce the night energy standby consumption by isolating standby equipment from the mains.
2) **Reduction of Warm-up period.** During early mornings and before the operation of large processing, there is a long warming-up period were the machines are turned from the standby status into ready to operate mode. It is therefore recommended to reduce the warming up duration to the absolutely shortest period of time.
3) **Put in place shut-down procedures for the breaks.** During processing periods, there are usually breaks on the activities, usually for coffee and lunch periods. During these breaks, the processing activity is stopped. By putting in place a shut-down procedure during the break periods, it is possible to save energy and therefore reduce the electricity consumption.

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4) **Reduction of Reactive Power.** Due to the nature of the electrical appliances within the Fish processing plant, there is a large presence of inductive load that create a large reactive power being used for operating the machines. The use of large reactive energy causes sanctions from the Grid Supplier and leads to extra electricity costs. By installing a power factor corrector for the Fish processing plant, it will be possible to reduce the amount of reactive power used and reduce the cost of electricity bills.

QUANTIFICATION OF RENEWABLE SYSTEM CONTRIBUTION.

Electricity can potentially be generated locally by a Renewable Energy System (RES). Such a system could reduce the amount of energy imported from the grid, reduce the cost of electricity consumed and therefore reduce CO2 emissions associated with the Fish processing plant.

The Renewable Energy systems that potentially can be considered for Scalloway Harbour have been initially shortlisted as:

- **Wind Turbine**
- **Solar Photovoltaic**

Even if the Shetland Islands have one of the best wind resource in UK and Europe, a Wind Energy System is not recommended because of the following site features:

- Scalloway harbour has a small surface footprint with very congested activities and several organisations operating within the same area. Therefore there is a very little space available for installing a Wind Turbine.
- The presence of wind turbulence also means that the area not fully suitable for Wind Energy. In fact the prevailing Wind Direction in Scalloway Harbour is South West. This direction is obstructed by surrounding hills that will affect badly the performance of the Turbine for most of the Year.

Though there are substantial wind turbulences, and the area is surrounded by hills, wind could still be investigated using the weather data downloaded throughout 2012. Note that this was not performed due to the above reasons, but can be a viable option if the harbour organisations are looking to reduce their emission footprint.

On the other hand the organisation within Scalloway harbour have extended surface footprint available on the roof that can potentially be used for installing Solar Photovoltaic systems.

The Estimation of Energy Production for solar photovoltaic systems has been carried out for each zone in relation to the location and orientation of different roofs. The total Energy that could be generated by the solar photovoltaic is about 192.7MWh. This represents about the 17.5% of the total energy used during a full year.

The economic and environmental benefits of a solar photovoltaic as installed at Scalloway harbour are the followings:

- Production of Green electricity at no cost (apart from the initial capital investment) locally with zero CO2 emission.
- Energy savings from not using imported electricity.

- Revenue income through the Feed In Tariff (FIT) Government scheme that rewards the energy generated by renewable sources.
- Selling surplus green energy exported into the grid.

Currently the Shetland Islands have a network grid that is restricted and with limited capacity to absorb intermittent renewable energy into the network. The ability to connect a solar system into the network requires permission and approval of the local DNO.

The current plan for developing a large Energy storage system in Shetland would facilitate the connection of Renewables into the Grid. However there is no guarantee that this option will receive granting from the grid operator.

CONCLUSIONS

The application of the strategy led to several major outcomes. First, it was shown that smart grid applications are technically feasible for Scalloway harbour; hence this could be applied to other European small to medium harbours. Second, it was found that though smart grid applications are technically feasible in many small to medium harbour setups, their application would prove extremely challenging to implement in Shetland and could not be guaranteed. This was due to the fact that the Shetland Islands are extremely grid constrained and are effectively operating as an off-grid system, with no connection whatsoever to the United Kingdom national grid.

The Shetland Islands have always had great difficulty in maintaining and managing grid stability. With the inclusion of renewable energy systems, it is understood that managing the Shetland grid has become very difficult. In fact, at the present time, it is almost impossible to connect a renewable production system to the grid, hence the limited potential for a smart grid system in Shetland. Though smart grids are meant to help with the introduction and increase of renewable energy systems, it was shown that there is a need for the installation of an energy storage mechanism in order to keep the grid balanced. The energy storage mechanism would act as storage when there is excess renewable energy generation. It would then act as a generation source at times when no renewable energy is available, but high harbour load demand.

It was therefore concluded that a system based on smart grids, VPP, energy storage and renewable energy is technically feasible in Scalloway. However, there are several challenges to make this happen, some of which are legislative, technical, financial and public acceptance.

The overall harbour energy analysis picture identified a number of key issues that could reduce the energy outgoings of the principal energy user in Scalloway. These issues allowed for a set of recommendations to be drawn out. The recommendations included: a) the installation of a renewable energy system, b) reduction of the use of standby equipment by disconnecting them from the grid outwith working hours, c) reduction of equipment warming (starting up) time, d) the production of a new internal policy for equipment shut down

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procedure during staff breaks and e) installing a power factor corrector for reducing reactive power.

By applying the above five simple measures, it is possible to reduce the operative cost and increase the efficiency of the process within the harbour. Therefore, if the harbour stakeholders choose to follow the recommendations, they have the potential to become more profitable. They will also have the ability to utilise their savings to invest in other areas of their business, leading to the creation of jobs and wealth at local level.

In conclusion, the application of simple measures in any harbour can lead to savings. The returns are financial, decreased CO2 emissions, better application of resources, new policies and wider implementation of green technologies in harbours across North Sea Region. In addition, the developed strategy can be applied to any harbour, whether small, medium or large. It is clear that if Scalloway harbour was grid connected to the mainland United Kingdom, then the implementation of latest e-technologies such as smart grids would have been easier, and thereby lead to a much higher return and wider application of renewable energy. To conclude smart grid technologies are key to harbours and easier to implement in a grid connected setup.

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WP 3.5 Application of Smart Energy Networks
Technical and Economic Analysis
Summary results of showcase Zaanstad, case study REloadIT

Author: Municipality of Zaanstad

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1.1 Introduction

The e-harbours report 3.7 focuses on the *organizational and legislative aspects* of smart energy solutions. A long list of general barriers has already been composed (deliverable 3.3).
The report 3.7 addresses the analysis on a local basis (country/city/harbour), where the smart energy solutions are hampered.

This e-harbours report 3.5 focuses on the *technical and economical aspects* of smart energy solutions. The scope of WP3.5 is the translation of the 6 universal business cases (e-harbours report WP3.4) on the level of every showcase. It gives an overview of the potential for the exploitation within the existing local (national) rules and regulations.

This document summarizes the results for the case study REloadIT at Zaanstad.

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:

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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 your context.

1.2 The strategy in showcases Zaanstad

The goal of this case study is to examine how to optimise the exploitation of renewable energy combined with electric mobility. Two strands of work have been defined:
1: The software development of the REloadIT smart grid application; a real demonstration project of a smart grid system.
2: An inventory to the different business cases the smart grid application could be based up on.

Furthermore several stakeholders were consulted: end-users and operation officers of the municipality of Zaanstad, suppliers of the charging infrastructure were involved during the development process and testing of the application. DSO and TSO's were consulted for the services they could offer for the development and exploitation of a smart grid.

The task of the development of the software and the analyses of the business cases was subcontracted to an external smart grid consultancy company EnergyGO.
This document focuses on the technical and economic issues for exploiting a smart grid system.
The software application has been described in appendix A.

1.3 Scope of the e-harbours showcases in Zaanstad

The main objectives to be addressed are:

- How to optimise the usage of renewable local energy to be consumed by the electric cars of Zaanstad.
- Develop and demonstrate the capability of the smart grid application under practical conditions: i.e. the reliability of the ICT-system and availability of electric cars, the user friendliness etc.
- Determine the available flexibility under different scenario's, and determine the economical value of the availability flexibility.
- Organise stakeholder meetings with key players.

Parallel to the development of the Smart Grid application, a "smart energy contract" was negotiated with an energy supplier.

Deliverables REloadIT:

- Software application REloadIT
- Business cases assessment report EnergyGO (Dutch)
- Minutes stakeholder meetings.

1.4 Optional: Extended/limited scope

- Parallel to the development of the Smart Grid application, a "smart energy contract" was negotiated with an energy supplier. Apart from incentives for energy reduction, the smart part of the contract was the introduction of local balancing of productions and consumption. Read more about the contract on: http://eharbours.eu/wp-content/uploads/Boekje-Energie-inkoop-congres-ENG-versie.pdf
- A local and major spin off at the Municipality of Zaanstad was the cooperation with different stakeholders on the development of a "smart and open energy system". This system aims to reuse residual industrial heat for housing, hospitals, swimming pools etc. The smart part of it is the connection of this city-heating system with 'green power to heat'. The basis idea is tot introduce balancing capacity/flexibility with the heating system. Read more about the contract on: http://eharbours.eu/uncategorized/cooperation-large-end-users-and-consumers-on-smart-grid-zaanstad
- A recently developed tool by our regional grid operator Alliander, called 'Sustainable Energy D-cision Tool', is used and tested to estimate the financial outcomes from different perspectives

(energy supplier / grid operator / prosumer). This is not further elaborated as part of the showcase.

2 Summary results

2.1 Case study REloadIT

2.1.1 Introduction

The municipality of Zaanstad aims to be climate neutral in 2020. Local renewable energy production, as well as clean mobility is stimulated. Within the REloadIT project a smart grid system has been developed tested to examine whether the benefits of renewable energy production can be matched with flexible energy consumption.
Subsequently, several business cases were analysed to see which business case is the most viable one. The parameter used to indicate the value of a smart grid application is:

Flexibility: that is the percentage of cost reduction of the energy bill, by exploiting the flexibility within a process. In the Zaanstad show case: the shift in time and intensity of the charging current of the batteries of the electrical vehicles.

2.1.2 Investigation summary.

Available information

- The power consumption profile of the car fleet being logged by the REloadIT data base.
- Load profile electric cars of the Netherlands based on European project GRID-4-Vehicles.
- Whether profiles of wind speed and solar radiation of the Netherlands.
- Report universal business cases Vito/HAW. http://eharbours.eu/wp-content/uploads/e-harbours_Strategies-and-Business-Cases-for-Smart-Energy-Networks_wp3_4.pdf

Preconditions analyses

- The electric cars are operational during all seasons, 24 hours a day.
- Base line scenario. For the determination of the amount of flexibility as defined by RGU for the benchmarking, the non-smart charging option for each scenario is used as the base line.
- Tariff structure applied for the simulations and analyses of the cases:
  - Standard tariff : 0,059 Euro/kWh
  - Peak or day tariff : 0,065 Euro/kWh
  - Off peak or night tariff : 0,049 Euro/kWh
  - Wind tariff : 0,06 Euro/kWh
  - Tax 1 : 0,11 Euro (usage <10000 kWh/year)
  - Tax 2 : 0,05 Euro (usage >10000 kWh/year)
  - Tax 3 : 0,01 Euro (usage >50000 kWh/year)
  - Fixed tariffs : 380 Euro discount on "tax 1" user, discount
    : 175 Euro "tax 2" user, per grid connection
  - PV - energy : "accumulating demand and supply (e.g. salderen)
  - Whole sale market : APX the Netherlands based on 2012 tariffs.
- For all scenario's we assume tax 2 as precondition.
- Battery specifications: Based on the theoretical assumptions, the total capacity of a battery is 100%. For the analyses we assume a battery charge/discharge cycle efficiency of 90%, lowest state of charge: 20%. Unlimited number of cycles allowed.

Predefined business models

For the REloadIT showcase we considered Contract optimization for the Zaanstad car fleet, as well as trading on the wholesale market. For a 1000 cars case study, we examined a BC with trading on the wholesale market. Balancing group settlement is not valid for the direct involved stakeholders of the project.
Due to the actual small scale of the REloadIT showcase the predefined options: *Offer reserve capacity* and *Offer further grid stabilization* are not suitable as business models now.

Business cases analysed

The investigated business cases are presented in table 1. Business case (4) is based on the fictitious rollout of 1000 charging stations upcoming years in the region at 35 municipalities.

Business case – name	Business case – description
0. EV (base case)	Charging 16 Electric Vehicles (EV)
1. EV + PV + salderen	Smart charging 16 EV with standard energy contract & production of solar energy with standard revenue ("*saldering*")
2. EV + PV + demand shifting	Smart charging of 16 EV on locally produced solar energy with standard energy contract and standard revenue
3. EV + PV + demand shifting	Smart charging of 16 EV on locally produced solar energy, including smart cost management (day/night tariff, optimal contracted load capacity)
3. EV + PV + APX	Smart charging of 16 EV on locally produced solar energy, including smart cost management (APX)
4. 1000EV + PV + APX	Smart charging of 1000 EV on locally produced solar energy, including smart cost management (APX).

Table 1: Investigated scenario's.

Results quantification of the flexibility

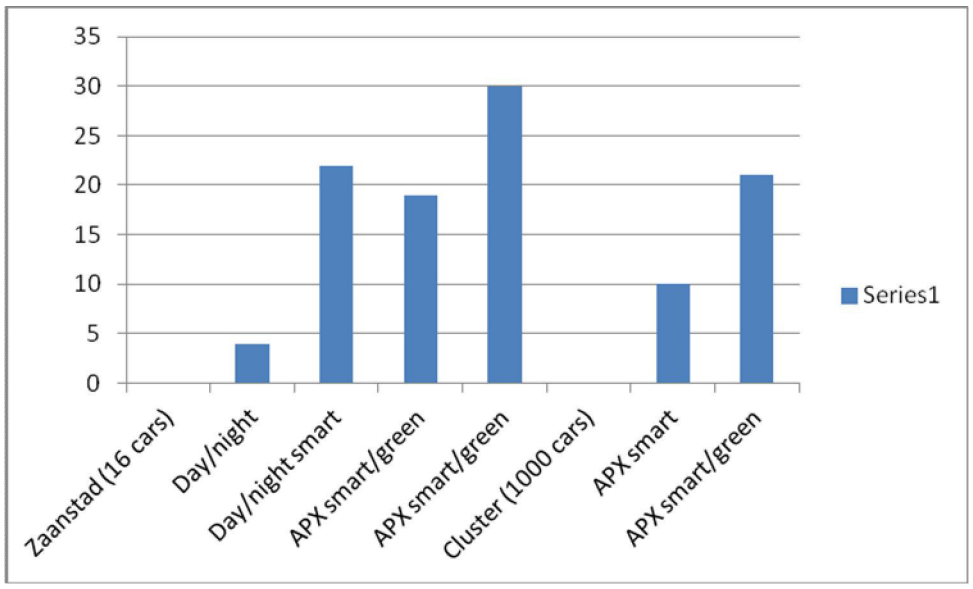

Figure 1: Percentage flexibility due to flexibility within the process of charging batteries.

3 Conclusions

- Electric cars seem to be the **ultimate source of flexibility** (15-30%). Although technical specifications of batteries may influence the economic viability caused by negative influence on the life cycle of the batteries, by charge- discharge algorithms.
- Financial gains are a main driver by **avoiding** taxes and networks costs.
- The present definition of private network avoids exploitation of renewable sources of energy other than on the local estate. Up scaling is thereby hampered.
- **Present tariff structure** hampers private customers to enter flexibility market. An only day/night tariff is available.

4 Lessons learned

4.1 Technical issues

Lessons learned

- Zaanstad specific:
    - Charge-only infrastructure is not fit for net balancing
    - Charging stations of the Zaanstad region not integrated in one ICT-entity
    - Possibilities depend highly on the generation or type of electric cars used for the show case i.e. the specification of the batteries used.
    - At the moment it is technically not possible to feed electricity into the grid. The actual charging station was not designed being able to be used for discharging batteries.
- Recommendations
    - Upscale test with more users and type of electric cars.

- Upscale test with more flexible energy consumers. For example, integration of water pumps, combined water and energy storage, and renewable energy systems (wind and solar).

4.2 Economic/organisational issues

Lessons learned

- Matching of flexible energy demand with variable (green) energy production has proven to be an economical value.
- Under present conditions a smart grid development still needs additional financial support.
- There is no way (yet) to benefit from the flexibility available in large scale e-mobility, because:
  - No clustered access to the flexibility market possible
  - The tariff structure is not supporting flexibility
  - Investments costs of a smart grid project are considerable.
- Up scaling is necessary to optimise the REloadIT application and its financial benefits.

4.3 Recommendations

- Practical : Start upscaling by exploiting the (huge) flexibility of large vehicles.
- Policy : Add an incentive on taxes and network operating costs

4.4 Ideas for further investigation

- Examine market models to have access to system balancing market.
- New innovative financial market models are needed to match energy demand with flexible renewable energy production.
- Think about mixed market option in order to benefit from different business cases.

5 References

- *Website of REloadIT: www.reloadit.nl*
- *Available presentations and brochures, refer to e-harbours website: http://eharbours.eu/showcases/showcase-zaanstad*
- *Report on business case study, EnergyGO*
- *Whether profiles of wind speed and solar radiation of the Netherlands.*
- *Report universal business cases Vito/HAW. http://eharbours.eu/wp-content/uploads/e-harbours_Strategies-and-Business-Cases-for-Smart-Energy-Networks_wp3_4.pdf*

Appendix A: Concepts REloadIT application

The REloadIT project has been launched at the 1th of March 2013. The usage of application is still under test. It comprises the test of the reservation system. The findings during these tests are fed back to the operator/administrator of the system. Final phase of the project was to evaluate whether REloadIT objectives have been met, and define recommendations to be instrumental to the sustainable mobility plan of the municipality. Major objective is to guarantee the optimum usage of the electric vehicles. The technical barriers encountered during these project phases, including the lessons learned, are described in paragraph 2.1.2.

Within the REloadIT, the following phases can be distinguished common to software development process : Specification phase, design phase, implementation, commissioning and testing phase.The specifications of the functional and the technical design of smart grid were defined by smart grid specialists from VITO in close corporation with the municipality of Zaanstad . This specification document has been used as basis for the tendering process. The REloadIT smart grid software application has been developed and deployed by a Dutch company EnergyGO.
Since March 2013 the municipality Zaanstad is testing their smart grid. This means that the energy demand to charge the batteries of the electric cars matches -as smart as possible- the variable electricity production of the solar energy systems. The smart grid algorithm is based on optimisation of the usage of the cars and weather forecasts, and the load management system (charger) of the smart grid. Based on rules that are calculated by the developed software application.

<u>The basic rules are:</u>

a. Maximize the use of the available renewable energy (three or four solar energy systems and an optional (virtual) wind turbine) to charge the electric cars. The surplus of renewable electricity is supplied to the municipality of Zaanstad through the distribution grid.
b. Guarantee that the state of charge of each electric car is sufficient for the next planned travel. By means of a car reservation system the usage of the electric cars is intelligently planned. Taken into account the calendar containing travel times, travel distance, and time the battery has to be fully charged. The aim is to prevent that at anytime, a driver is held up by an empty battery.
c. Charge the batteries as much as possible at low energy tariffs. A day ahead the data of the APX-price real time are imported. In the tests which are running during 2013 a limited set of cars is included. However for the various business cases calculations the information for all charging stations and electric vehicles is incorporated and extrapolated. The municipality has now 16 charging stations, the business cases will also encompass one scenario with a larger share of e-vehicles and charging stations (based on the aimed volumes of the Metropolitan Region Amsterdam).

To gain insight on the economical value of the match of charging electric vehicles and locally produced renewable energy, 4 business cases scenarios have been selected. Calculations have been carried out to determine the flexibility and to analyse the potential cost reduction for each scenario. The outcomes of these analyses are presented in paragraph 2.1.2.

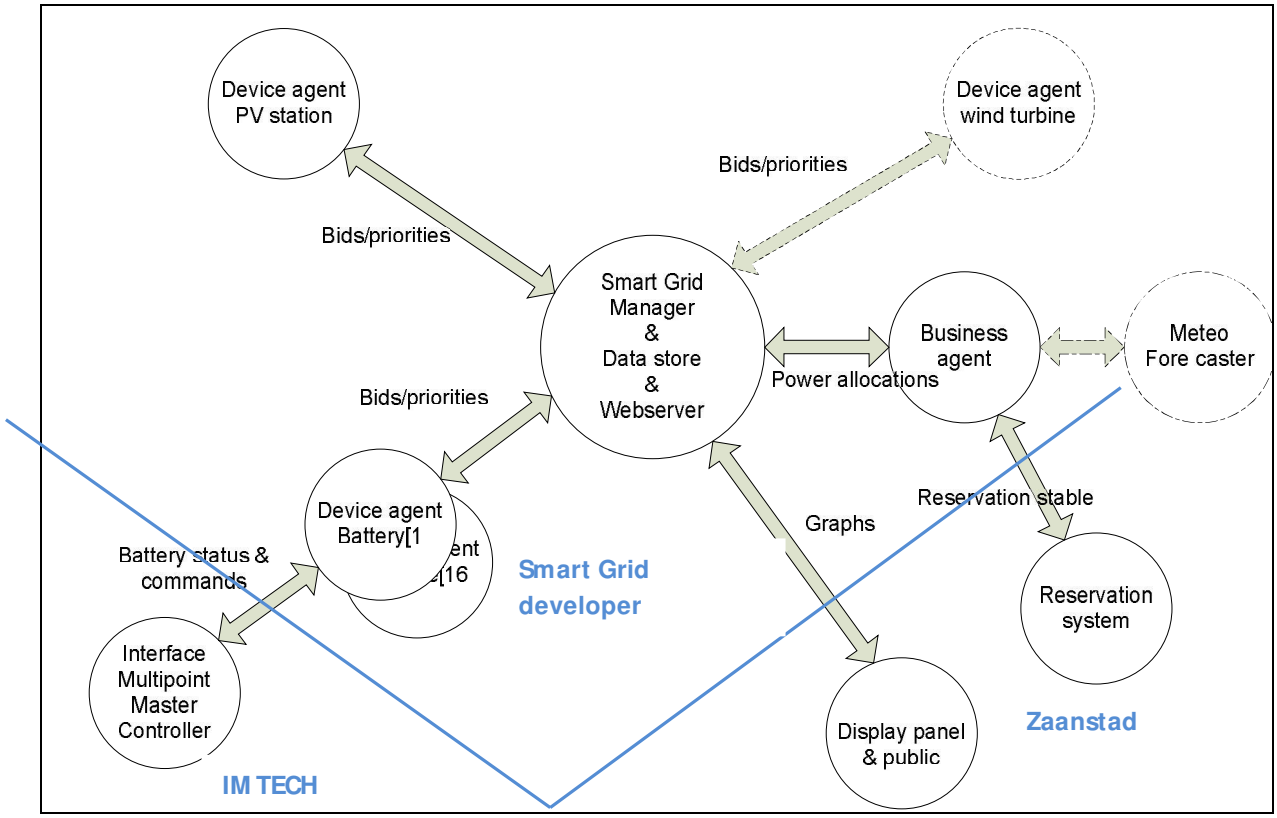

Figure 2: Software architecture proces data flow ReloadIT

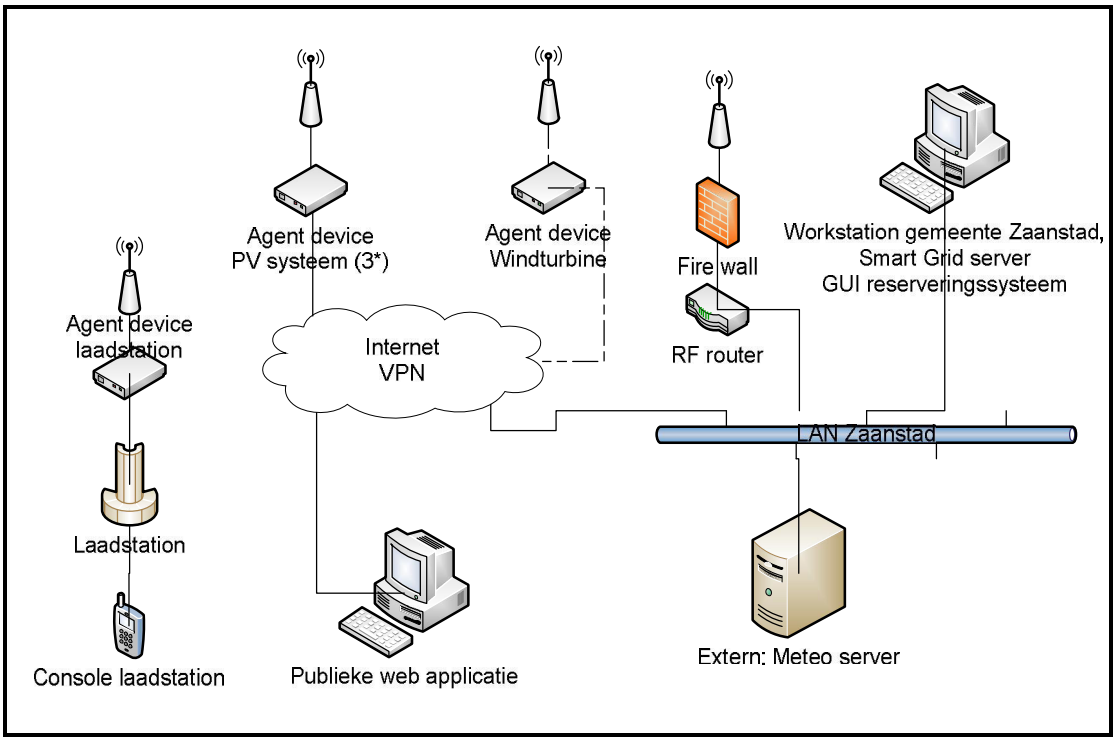

Figure 3: ICT infrastructure REloadIT

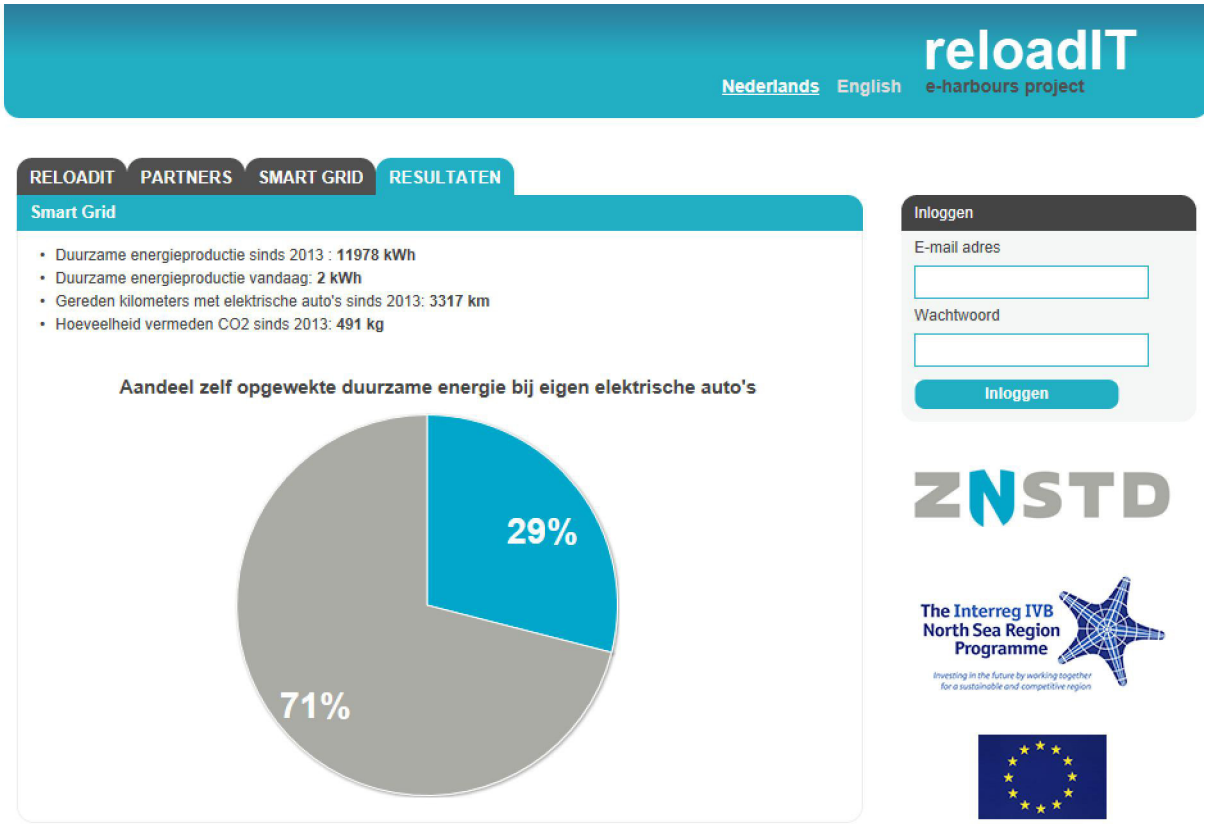

Figure 4: Web site REloadIT

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WP 3.5 Application of Smart Energy Networks
Technical and Economic Analysis
Summary results of showcase HoogTij

Author: Simon Lubach

Photo: Municipality Zaanstad

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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 both technical/economical and organisational/legislative conditions is crucial.

The e-harbours report 3.7 focuses on the *organizational and legislative aspects* of smart energy solutions. A long list of general barriers has already been composed (deliverable 3.3).
The report 3.7 addresses the analysis on a local basis (country/city/harbour), where the smart energy solutions are hampered.

This e-harbours report 3.5 focuses on the *technical and economical aspects* of smart energy solutions. The scope of WP3.5 is the translation of the 6 universal business cases (e-harbours report WP3.4) on the level of every showcase. It gives an overview of the potential for the exploitation within the existing local (national) rules and regulations.

This document summarizes the results for the showcase HoogTij in Zaanstad.

1.1 Universal business cases: 6 possibilities defined

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:

1. 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.

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The scope of WP3.5 is the translation of the “theoretical” business cases of WP3.4 into realistic business cases in your context.

1.2 The strategy in showcase HoogTij

Development locations of business parks are a great chance to integrate a smart energy network and to implement renewable energy. The strategy of the showcase is to identify potentials for a smart energy network on an industrial development park, using a case study: HoogTij.

Identification
The identification of flexibility in this showcase was established by a desk study. Industrial processes which offer a source of flexibility where investigated in literature. From the flexible processes that are described in literature, one example was identified to potentially settle on HoogTij. This process was under consideration to be developed at the site, and thus an interesting case to study for an application in a smart energy network.

Quantification
Since the installation was not constructed yet, and the properties where not known, a number of assumptions had to be made on its characteristics. To quantify the flexibility, a simulation model has been developed, which could calculate the various constrains affecting the flexibility. The major constraints for the flexibility could easily been changed in the model, to seek for a technological and economic optimum for the installation.

Valorisation
The value of the flexibility depends on the type of business case that can be applied. Apart from the universal business cases proposed in [1] an additional business model was tested. The simulation model gave clear estimations on the value of the flexibility.

Exploitation
To exploit the economic value of the flexibility in a maximised way, cooperation needs to be made with a number of stakeholders. A few alternatives where proposed for exploitation. The most viable solution seems cooperation as a ‘local sustainable energy company’.

Up scaling
Up scaling or clustering, for instance with similar installations elsewhere, was not considered in this showcase. This case was already quite complex; more extensions seem not feasible at the moment, as it already had some uncertainties to deal with.

Introduction renewable energy
Renewable energy from wind turbines is an integral part of the showcase, and is thus considered.

1.3 Scope of the e-harbours showcase HoogTij in Zaanstad

The aim of showcase HoogTij was to seek for new ways to increase the sustainability of the area and to assess the potentials for a smart grid. The Municipality Zaanstad aims to become energy neutral,

hence the possibilities to develop HoogTij in an energy neutral way fits in this ambition. Several concepts for renewable energy production where already investigated for HoogTij. However, exploiting the flexibility in a smart energy network was not yet considered.
The showcase HoogTij was initiated in cooperation with a student from the Eindhoven University of Technology, as part of a graduation project.

The showcase HoogTij proposes a smart energy network on a local scale, which includes the following:
- Three or four wind turbines
- A district heat/cold network with heat pumps
- Buildings connected to the heat/cold network
- Active and passive heat storage, to provide flexibility in the production of heat.

The technological feasibility of the proposed smart energy network is investigated in the showcase, as well as the economic value of the flexibility and the viability of the business case as a whole.
This showcase has been analysed using a simulation model and weather data. Since the components of the smart energy network are in planning phase, no actual energy consumption data or specific type of equipment where known.

Deliverables in this showcase include; final report 'Smart grids on industrial areas' [2], the simulation model, and this report.
From the six universal defined business cases **contract optimisation** is considered as a viable solution. Additionally, a specific business case for a local 'micro grid' has been investigated (see extended scope).

1.4 Extended scope

The scope of the showcase was extended to include scenarios for optimised use of local generated wind energy. To find a business model that stimulates the use of wind energy, a price advantage is required. This can be achieved by placing the wind turbine on the same grid connection as the installation for the district heat network. The mutually traded energy has a price benefit compared to energy bought from the grid, and therefore increases the business case. In the showcase, two scenarios including local use of wind energy where analysed: A private grid, (wind turbine and heat pump share the grid connection) and a smart grid, where the use of local produced wind energy is optimized.

2 Results

2.1 Showcase HoogTij

2.1.1 Introduction

In this showcase a smart grid application has been analysed for the industrial development HoogTij. The aim for HoogTij is to create a sustainable energy infrastructure: Development of wind turbines is taking place and a district heat/cold network is being planned, which can be used to heat the buildings on the site. One of the alternatives is to produce heat and cold for the heat grid by a heat pump. Heat pumps are efficient devices, which use heat from the surrounding air or (ground) water to produce heat. These heat pumps can have flexibility in their operation, together with the projected wind turbines, the ingredients for a smart grid application are identified (figure 1). To be able to operate the heat pump in a flexible way, heat storage should be available to buffer the heat

temporarily. A heat buffer tank or the mass of buildings can be used to store heat, so that the production of heat can be optimized on the availability of energy from wind. Currently, only a few companies have settled on HoogTij, however, a new detention centre is planned at the site, which has a considerable demand for heat and cold. In a study on the district heat grid, the detention centre is observed as the client with the highest demand for heat. Since it has the possibility to use its concrete structure as passive heat storage, the detention centre became an important object in the showcase.

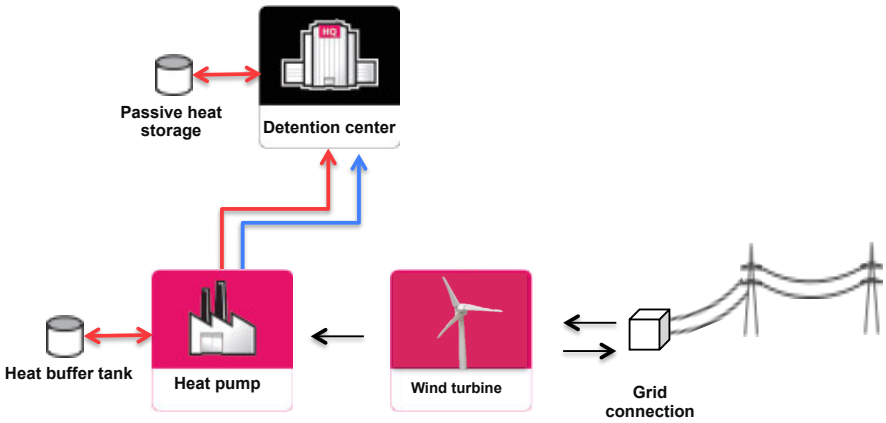

Figure 1: Proposed smart grid scenario. Production of heat is optimized to the availability of wind energy, by using heat storage in building mass or heat buffer tanks.

2.1.2 Investigation summary.

Available information

In this showcase, a concept for a smart energy network was developed, rather than an analysis of an existing installation. Thus, no measurement data or technical information was known. A study on the feasibility of the district heat/cold network was an important input for the showcase [3]. To develop the simulation model, various sources of information and (weather) data where used:

- Wind speed measurements and a wind turbine power curve, to simulate wind energy production
- Climate data to estimate heat demand of buildings
- Coefficients of performance of heat pumps
- Assumptions on the performance of building materials used.

Power consumption & flexibility analysis

The concept of using heat pumps in a smart grid was already described in scientific literature. Since the installations on HoogTij will have a considerable dimension, the business case seems viable. To quantify this, the simulation analysis was used to model the power consumption and its flexibility. The flexibility of the installation depend on the heat demand over time, but can be increased by adding some extra capacity in the installation and to increase possibilities for heat storage.

Analysed scenarios

A number of scenarios where analysed in the showcase:

- Business as usual
- Contract optimization; making use of day/night tariffs
- Private grid; the heat pump shares a grid connection with one of the wind turbines.
- Smart grid; wind energy use is optimized.

In the scenarios private grid and smart grid, wind energy can be traded ‘off the grid’ since they share the same grid connection and e.g. transport costs can be avoided. The savings in these scenarios

where up to 23%, making the business case for the heat grid much stronger. Additionally, the heat pump could be supplied for 80% on wind energy, providing clean and renewable energy to the end users on HoogTij.

3 Conclusions

3.1 General Overall Conclusions

The case of the industrial development HoogTij is a good example for a possible application of smart grid technology. Flexibility that is present in the system of the heat network can be exploited in a smart grid. The economic benefits are so significant, that it makes the heat network profitable. Hence, this case can really improve the sustainability of the development of HoogTij.
The business case is strongest when the wind turbine is placed on site and the energy can be traded directly (private and smart grid scenario's). The added value of the flexibility turned out to be an additional cost saving of up to 5%. The graph in figure 2 illustrates the potential costs savings.

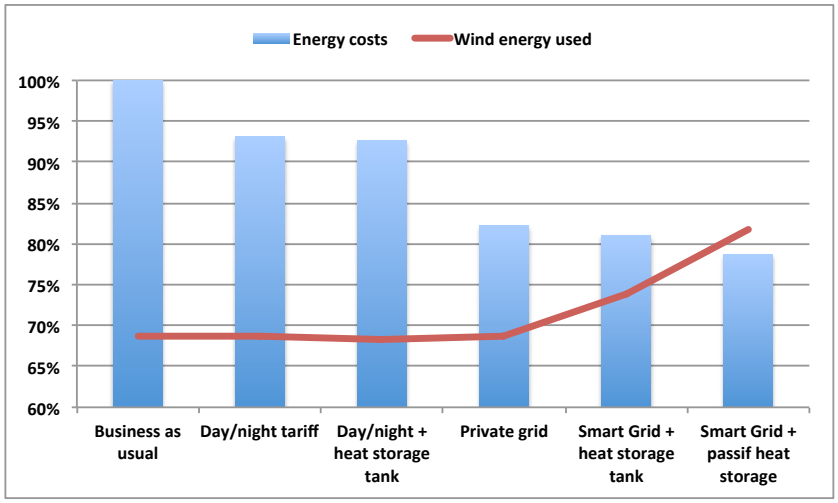

Figure 2 Results of energy costs and the fraction of wind energy that is used in different scenarios of the simulation.

The concept of the showcase can be applied widely, since heat pumps are often used in modern buildings. More installations can be clustered to a pool, to better exploit the flexibility. Such a pool of installations can play a significant role and exploit more business cases, for instance by trading energy on wholesale markets or offer reserve capacity.

4 Lessons learned

The showcase illustrated that significant business cases can be found in the quest for flexibility. The industrial sector has much potential to exploit flexibility that is present in their installations.

Looking for flexibility during the design phase of a project makes good sense; minor adjustments in the design of the installation can significantly increases the flexibility. To 'act smart from the start' will have a great impact in the results that can be achieved.

The technical issues in this project where sometimes complex, but can be overcome with some ease. The biggest challenge is to get all the stakeholders organised and find consensus on a solution. In the development of the industrial area of HoogTij, quite some uncertainties and challenges where faced regarding the slow pace of issuing of the lands. A smart energy infrastructure can be a unique selling point of such an area, yet it is also another challenge to develop.

4.1 Ideas for further investigation

For further research, it can be recommended to investigate a smart grid application for the municipal pumping stations. These pumping stations have a significant consumption of energy, and have flexibility as well. In cooperation with the stakeholders such as the water board, energy supplier and the grid operator, the flexibility can be exploited whilst all partners can experience benefits. Such a project can contribute to the innovative nature of the area.
This leading role in the field of energy can contribute to the business climate of the area. For both existing and new companies that consider settling, the knowledge and innovation on smart energy networks can be a strategic asset and contribute to economic welfare of the region.

5 References

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