

# Smart Grids and Virtual Power Plants

Point of departure. 10 March 2011

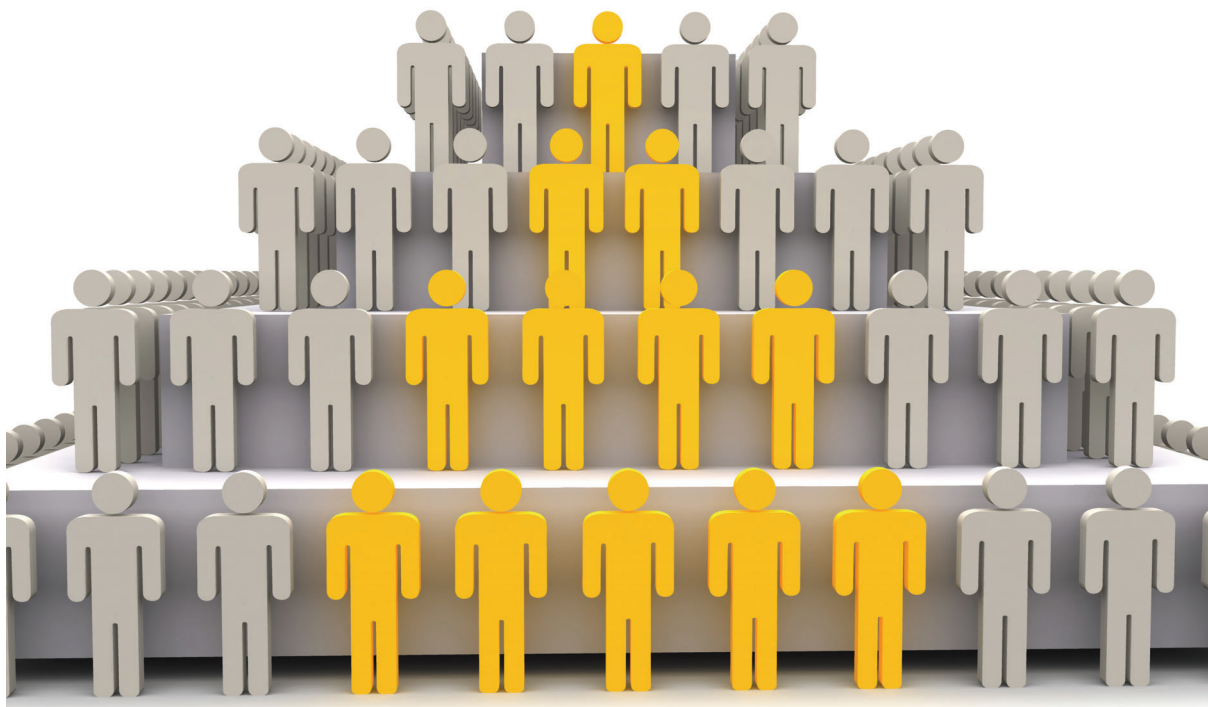


Photo: Colourbox



# Summary



*The project e-harbours brings together harbour cities and research institutions from the North Sea Region. They combine their efforts to increase the production and use of renewable energy, and to reduce the emission of greenhouse gasses. One of the main goals of the project is to develop the potential of Smart Grids, electricity networks that are more diversified and more flexible, and make it easier to incorporate sources of sustainable energy. In the electricity sector, both predictability and flexibility of producers and users have become commodities that carry an economic value. That value is rising as the electricity networks get more diversified and less controllable. Users and suppliers of electricity that help to decrease imbalances in the system can claim a piece of the pie. On the other hand they must be willing to hand over some control over their activities to the electricity system. In this field major technological and social innovations are called for. They could open up a huge potential for the harbour regions in North Western Europe.*

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# 1. Introduction



The harbour areas of the North Sea region are nodal points in the international transport network, and preferred locations for a wide variety of industries. These areas transport and transfer huge amounts of commodities, including energy related products like coal and oil, and play a central role in the energy system of our countries. The use of energy in the harbour regions is immense, but the level of energy efficiency remains too low, and the share of renewable energy sources, although growing, is still disappointing. Both from the economic viewpoint (the energy costs are too high) and from the environmental perspective (the emission of CO<sub>2</sub> and other greenhouse gases is excessive) there is an urgent need for improvement.

The harbour regions around the North Sea have many traits in common. They operate in more or less the same climate, the same cultural setting, the patterns of energy use over time are much alike. These regions can benefit greatly from cooperation and the exchange of experiences. That is the rationale for the e-harbours project, which has as its main goal to enhance the production and consumption of renewable energy in the harbour regions. Supported by a subsidy from the Interreg IVB-program of the European Community, we assist the participating regions in developing 'showcases' that demonstrate the possibilities of new techniques in this field.

One of the core aims of the e-harbours project is to enhance the development of Smart Grids in the participating harbour regions.

## ***What is a Smart Grid?***

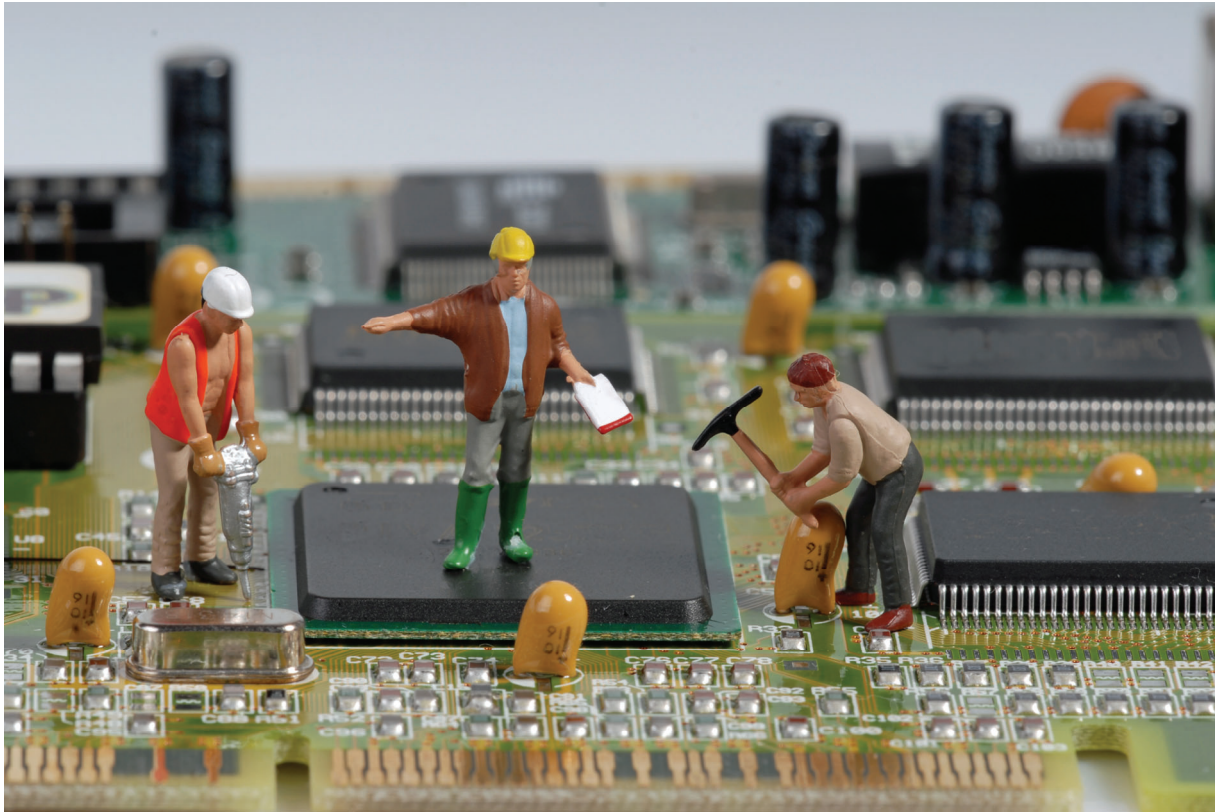
*At e-harbours, we define Smart Grid as an electricity network that is adapted to the introduction of renewable energy sources. Unlike the old fashioned networks, it is not dominated by a single electricity producing plant (or by a number of such units).*

*Decentralisation of production is a key element of a Smart Grid, which maintains its balance (an absolute necessity for electricity networks) by using innovative techniques. A Smart Grid is managed in a more sophisticated way, reading sensors and operating switches both on a high level in the network (the high voltage part of the system) and in the distribution part of the net.*

*Since the term 'Smart Grid' has become very fashionable, a proliferation of different definitions is used, blurring the meaning of the concept. One popular definition of a smart grid makes sense: an electricity network that is coupled with an ICT-network. This definition underscores that the gathering of information about developments in supply and demand is vital for a smooth operation of the electricity network. Of course we only begin working towards a smarter electricity system when we take decisions on the basis of the information gathered, thereby improving the efficiency and the sustainability of the network.*



## 2. Why Smart Grids are necessary



The consumption of electricity in Western European countries keeps on growing, even at a faster rate than the growth of the economy. Bad news for the environment, if not an increasing part of the electricity generated in the Western European countries would stem from renewable sources. All countries represented in the e-harbours initiative stimulate the development of energy sources like wind turbines, solar power farms, tidal installations, co-generation of heat and electricity, etcetera. In this way we work towards the targets of our climate policy, which demands a further reduction of CO<sub>2</sub> emissions. Germany, the leader of the pack, intends to generate 35% of its electricity needs from renewable sources by 2020, about double the current amount.

The rapid growth of renewable energy sources creates problems for the electricity networks. The new sources of electricity (like wind turbines, solar power plants, co-generation facilities) are more diverse and less controllable, so the electricity companies have more trouble maintaining the stability in the network. Flexibility in both the production and the consumption of electricity becomes a key factor. **When we can define new ways to enhance the flexibility of the system, we enlarge the possibilities for the incorporation of renewable energy units in the electricity network.**

The more flexible the electricity grid gets, the less risk that the incorporation of decentralised production units into the grid will destabilize it. That is why the electricity networks in the harbour regions of Western Europe have to be transformed into *Smart Grids*.

In the next paragraph we zoom in on the functioning of an electricity network, to show why flexibility in the production and use of electricity is of such overriding importance.

### 3. Maintaining the balance in the electricity network



Even a decade ago, the electricity networks of Western Europe had a much more simple structure than they have nowadays. The networks were developed to bring electricity from a limited number of power generators (mostly using fossil fuels) to a large number of consumers, both industries and households. The power generating turbines are (at least partly) adjustable; the production can be raised or lowered when required. Then, as now, the rule was that all electricity produced has to be consumed immediately. It is not economically feasible to store large amounts of electricity for later use, so the production has to be adapted continuously to demand. When there is insufficient demand for the electricity produced, the frequency of the net starts to rise. This rise has to be contained by lowering the production of electricity.

The rise of renewable sources of electricity has changed the situation. Nowadays, the electricity distributors have to handle a much larger number of power generators, which are much more distributed geographically. And most installations that produce electricity from renewable sources can not be adjusted the way conventional power generating turbines can. A photovoltaic power farm keeps on producing electricity as long as the sun shines. A wind turbine delivers electricity to the net with every gust of wind. In some situations, these renewable sources keep on pouring electricity in a network that is already overloaded, increasing the imbalance between supply and demand. Electricity companies with a lot of wind turbines in their network have at windy times even been forced to administer negative prices, paying consumers to use electricity (as happened recently in the north of Germany and in Canada).

In short: the growth of wind energy, solar power, tidal generators and other decentralized sources of electricity raises problems for the companies that distribute electricity, making it ever more complicated to keep the balance in electricity networks that are less controllable.

This threatens even to hamper the further development of renewable energy. In some instances, electricity companies in Belgium felt obliged to prohibit the addition of new energy sources like wind turbines and photovoltaic installations to their networks, stating that they endanger the balance in the system.

There is a better solution to keep the production of electricity in step with demand, thereby stabilizing the networks: identify and employ new sources of flexibility in both production and use of electricity. Businesses and consumers can supply the flexibility that the electricity companies need.

## 4. The cost of stability

Electricity companies use different methods to guarantee the stability in their networks.

The moment a network gets out of balance they employ control mechanisms to restore balance. For example, when the frequency of the network is falling (the demand is too high compared to the production), they call into action production systems that stand waiting, starting with the most cost-effective units. This action involves costs, that have to be paid by the producers or end-users that produce the imbalance.

In balancing the network, electricity companies rely on the forecasts of their customers. Companies and institutions that use a lot of electricity have to declare in advance what amount of electricity they will need in specified hours (or even quarters of an hour) the coming day. This way the demand gets more predictable – when the customers do what they said they would do. The electricity retailers use contracts with a *take or pay*-clause. When you have ordered electricity for the coming day, you have to buy it. Even if you don't use the kilowatts, you have to pay for them. That is one way end users pay for any imbalance they are causing.



*Some customers of the electricity companies play an active role in balancing the network. For example, in Belgium a chemical installation of Tessenderlo Group accepts a balancing responsibility. Huge electrolysis installations (using Megawatts each) increase production when the demand for electricity is too low, and decrease production again when demand starts to rise. The electricity company in fact steers the production volume of the chemical installations. Tessenderlo Group is paid for offering this service to the network.*

The amount of money involved in (correcting the) imbalance in electricity networks is huge. Some calculations show that more than 10 percent of the total electricity bill paid by end users is connected to imbalance.

We can identify two factors that are of importance to the electricity suppliers:

- the stability and/or predictability of production and consumption of electricity.
- the flexibility that producers and consumers can offer.

Both factors are in fact commodities, they carry an economic value. For example, the consumption of a certain amount of electricity at a specified moment is a commodity. It can be traded. At the Exchanges of Belgium, the Netherlands, Germany you can buy or sell electricity consumption rights at certain specified moments.

And of course this same story applies to the production side of the system. Predictability and flexibility are commodities that carry an economic value. That value is rising as the electricity networks get more diversified and less controllable. Users and suppliers of electricity that help to decrease imbalances in the system can claim a piece of the pie.



## 5. The quest for flexibility



Flexibility – both in the production of electricity and in the consumption – is an important asset that helps electricity companies to maintain the balance in their networks. Most customers are not aware of the value of this flexibility that can be found in their day-to-day operations. Some big users of electricity, aware of the economic value of flexibility, and prepared to adapt their expenditure to the needs of the network, succeed in negotiating lower prices per kWh.

### ***The Flexible Warehouse***

*Suppose we run a stand alone warehouse storing vegetables in refrigerators. The average storing temperature is minus 20°C. The vegetables should not be allowed to warm up to more than minus 15°. On the other hand, the produce can be cooled tot minus 25°C without any damage done to the quality. We can make use of this bandwidth.*

*Suppose the electricity network is suffering an imbalance caused by a declining demand. Then our warehouse could use the excess electricity to lower the temperature in the refrigerated rooms. Later on, when the demand for electricity in the network picks up, we switch off the cooler, and allow the temperature to rise again to the desired level. In fact we achieved something that nowadays even the best batteries in the world cannot deliver: we created an economically feasible buffering capacity for electricity. We can negotiate with the electricity retailer about a KWh price that reflects the flexibility and balancing power we provide for the network.*

*Comparable projects involve water purification systems. In many cases it is possible to stop the purification process at certain levels, and resume the process again at a later moment. This way peaks in the consumption of electricity can be avoided, and stability in the system can be enhanced.*

In delivering flexibility to the electricity network, we also hand over some control over our production process. This can be tricky. Suppose the supplier of flexibility is a process involving bacteria. For the process to function properly, the temperature of the installation must be kept within narrow limits. Then the offer to the electricity company has to be defined quite precisely to prevent damages and malfunctioning in the primary process.



## 6. Organizing stability and predictability



The second commodity that has evolved out of the balancing problems of the electricity networks is stability and predictability. When we can restrict the variation in our production or consumption within narrowly defined borders, we are able to negotiate better contracts with the electricity companies.

The example of the stand alone warehouse is very simple. Companies that run big power-consuming processes tend to have their own production capacity for at least part of their power requirements. Also, a lot of processes require heat, and heat generators can be made much more cost effective by combining them with power production ('co-generation').

Suppose we have a number of production facilities, most of them concentrated in one location, which not only use great amounts of electricity, but also produce electricity. We can operate this cluster of producers and consumers as a Virtual Power Plant.

### ***What is a Virtual Power Plant?***

*The basic idea of a VPP is that a number of small scale production units of electricity can be operated as if they formed one huge power plant, like a conventional coal fuelled plant. Individual units (especially wind turbines and solar farms) cannot guarantee a stable production level around the clock, but the combination of different sources can. By evening out the different peaks we make our energy production much more predictable and stable.*

*The basic idea of combining single production units gets more complicated when we incorporate the end users in the system. Balance within our system can then be reached in different ways. Switching off a number of electricity consuming installations has the same effect as raising the production of electricity. Or we could decide to switch on big power consuming units (like electrical cars that have to be charged) at the moment production in the system is at its peak.*

*However, the core of the Virtual Power Plant consist of a coordinating mechanism, that takes coherent decisions regarding a number of production facilities and end users of electricity, resulting in a predictable and stable outcome. This creates better conditions for the introduction of new renewable energy sources. And the owners of the Virtual Power Plant can negotiate a much more favourable contract with electricity companies. (To make the story even more complex, it is also possible to coordinate a virtual power plant in such a way that it can offer extra flexibility to the grid.)*

## 7. Towards concrete business cases

It is clear that the harbour regions of Western Europe can profit from the new developments in the electricity system. The harbour regions can offer the space and the conditions that renewable energy facilities need. The proximity of warehouses and production facilities that consume and produce great amounts of electricity make it feasible to build coalitions, or even Virtual Power Plants.



One of the goals of the e-harbours project is to identify chances for big users and producers of electricity in the participating harbour regions. These chances concern:

- limiting and stabilizing the use of electricity
- identifying chances for flexible use of energy in the production process
- reducing energy costs
- enlarging the share of renewable energy
- reduction of the emission of greenhouse gasses

The Flemish research organisation VITO is involved in several projects in or around the harbour of Antwerpen, with companies trying to identify chances and seize the opportunities.

The business cases developed there can not just simply be exported to other harbours and other companies. The properties of the production process involved, the way participating companies are organised, and the state of the electricity network at the location can vary. Each of these factors has a great impact on the business case.

### ***Different business cases***

*For example, take a region that has an old electricity grid, operating at the limits of its capacity. When you plan to build a solar energy farm in that region, or want to install a series of heat pumps, or consider the purchase of a fleet of electrical vehicles that will have to be charged by the system, there is a fair chance that you are going to exceed the possibilities of the network. The network operator will have to invest heavily in rebuilding his system. This translates in higher costs for the electricity retailer, that make him less inclined to offer you favourable prices. In that situation, you could better try to combine investments in such a way that you get less dependent on the electricity grid. Or offer the network operator flexibility, by giving him the right to control certain installations so that he can keep the system running without additional investments.*

Each business case has to be researched, and thoroughly tested off line, before it becomes clear what the benefits are. But it is obvious that the rewards, certainly in the long run, can be huge. We advise local businesses and communities to start with small scale projects that can be combined. When the project begins to grow, it becomes feasible to aggregate production and demand locally. Then you can start thinking about taking balancing responsibility, and eventually start to trade at the spot market for electricity contracts yourself.

In this phase of the e-harbours project the main goal is to identify possible chances and the constraints that could hinder further development. It is important to research with the participating community's, institutes and businesses what the main obstacles are that we encounter.

## 8. Can households be involved?

Theoretically, the involvement of (groups of) private households could enhance the scope and the flexibility of a virtual power plant. Calculations show an average value of the flexibility that households could deliver to the electricity system of up to 50 euro per year. That may not seem a large sum, but when you take into account the number of households that could get involved, it amounts to hundreds of millions of euros per annum.

How this could work out in a household is shown by the following (still theoretical) examples:

- We fill the washing machine, and then have two options. Or we decide to push button A, and get the washing done immediately. Or we push button B, and know that the machine will start at some moment in the next four hours. What moment the machine starts is decided by the electricity supplier. (The first washing machines with an interface that makes this functionality possible will be introduced in the spring of 2011).
- We install an air conditioner, and let it keep the temperature in our living room at a constant 21° Celsius. We give the electricity supplier the right to stop this air conditioner for one hour per day, at a moment that suits the network best. The contract stipulates, that the temperature in our living room will not be allowed to exceed 22°C.



These examples presuppose that smart meters are installed in the households, and that two-way communication is possible between the meter and household machines. Also, it asks for a complicated communication protocol between the smart meter in a household and a central coordination point.

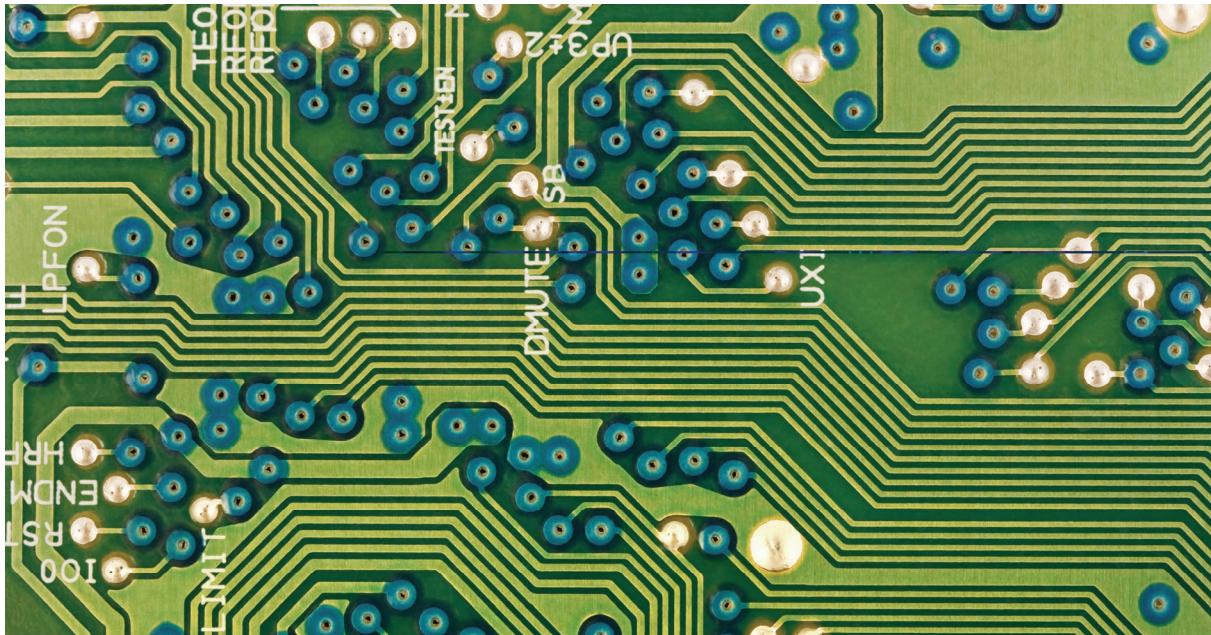
This seems quite a big investment for a small gain. But, when households begin to employ more powerful (and complicated) installations, like small co-generation units and heat pumps, and employ electrical cars that need to be charged, the amount of kWh involved goes up, and the flexibility program gets more profitable.

In the examples mentioned above we deliver some flexibility in our use of electricity to the network, thereby conceding some control over our behaviour and our energy use to the electricity company. Of course not all consumers will be prepared to accept this 'interference' by the electricity supplier in household decisions. Already in some countries the installation of smart energy meters in the houses of consumers – one of the prerequisites for making use of flexibility in the energy consumption – is halted by fears concerning the privacy of households.

The first examples where groups of households are combined to deliver flexibility to the network and negotiate better electricity tariffs are available. In Sweden some municipalities are experimenting with the system. In the Belgian city of Leuven construction has started of a new quarter that will operate as a small Virtual Power Plant. We expect the bulk of the consumers to follow these examples only hesitantly, also because of the legal right to choose your own energy supplier (which makes it more difficult to forge long term coalitions with groups of households) and tariff structures that sometimes send wrong signals to the consumer.



## 9. Constraints and possibilities



Projects that want to make use of the possibilities sketched in this paper meet constraints. Although these can vary depending on the locality and the country involved, some constraints seem to apply in every country involved. They could be defined and tackled in the course of this e-harbours project. We name the most important constraints:

1. In most countries, it is legally prohibited to exchange electricity between companies, and between consumers. When you produce electricity in excess of your own needs, you are not allowed to deliver it to your neighbour. The possibilities for the installation of private networks, with a combined access to the electricity network, are in most cases severely restricted by legal constraints.
2. In many countries the end-users have a legal right to choose their own provider of electricity. This can hamper the forging of long term coalitions.
3. Tariff structures differ wildly between countries. In some instances, the tariff structure gives completely the wrong incentives, impeding the saving of energy or the production by way of renewable sources. A remarkable example involves co-generation units in Belgian horticulture companies. The tariff structure made them so profitable (as long as they delivered electricity to the network) that the owners refused to stop them even when they had no use anymore for the heat that the co-generation units produced.
4. Safety and privacy issues. Building a coalition that involves the exchange of loads of information over the Internet raises questions about the protection of that information. Companies are very shy to share strategic information concerning production levels and technology, and rightly so. Consumers that think about installing so called smart meters are worried about their privacy.



## 10. Showcases



The e-harbours project aims to progress the Smart Grid agenda in European harbours by means of the following showcases:

- Optimal upload of sustainable energies in harbours, matching the supply of renewable energy to demand (Antwerp).
- E-monitoring, demand side management makes the smart grid more responsive to changes in the demand for renewable energy (Hamburg)
- E-label gives consumers insight in the environmental quality of the electricity they are consuming, and allows for differentiated tax rates on electricity according to emissions and waste produced (Uddevalla).

### 1. Optimal upload of sustainable energies in harbours (Antwerp)

Several harbours already provide for a relatively high amount of sustainable energy (for example wind energy), and a high level of cogeneration. The accessibility of these renewable and efficient energy sources is determined by electricity grid constraints. The challenge is therefore to develop a cost effective integration of local energy use and production. This can be done by an innovative concept combining existing ICT tools and a new business concept involving several stakeholders (from suppliers to end-users).

Main objective of the showcase is the development and proof of concept of an innovative business case to match supply and demand in an industrial part of the harbour. Renewable energy production is matched with flexible industrial use of energy (e.g. cool storage). Where feasible, energy storage will be included. This application will be integrated in a global strategy on integration of sustainable energy for the harbour.

The application of the innovative business concept includes stakeholders from the whole chain, beginning with energy suppliers/producers, up till the end users, regulators, and research institutions.

## **2. E-monitoring and demand side management (Hamburg)**

There are clear possibilities to connect demand for and supply of renewable energy in a smart way, resulting in lower energy use, lower CO2 production and lower costs. A first step towards this goal is systematic monitoring and research on demand response capacities. The focus is on technical infrastructure, and on the possibilities for integration into a municipal smart grid. This includes the development of innovative business concepts.

The main goal of the showcase is systematic research of the demand side management (DSM) capabilities of the technical infrastructure of the harbour and city of Hamburg. Analysis of typical urban development schemes concerning their DSM capabilities, development of innovative business concepts to integrate the flexible load as reserve capacity (positive and negative) into the smart grid platform at Hamburg Energy. Furthermore, pilots will be set up to investigate the possibilities for DSM based reserve capacity on the smart grid platform.

The research and pilot installation involve the following partners: The City of Hamburg, department of urban development and the environment (BSU), Hamburg Energy, harbour industries and engineering companies, the University of Applied Sciences (HAW Hamburg) and the Harbour City University (HCU) of Hamburg.

## **3. Energy label (Uddevalla)**

The power of the energy consumer is potentially very big. Consumers are getting more and more aware of this. This pilot focuses on the development of a label that provides detail of the content of the energy supply mix and resulting environmental implications with immediate online feedback in real time. Designing an electricity label or web-based information system displaying information about the primary energy sources used to generate a certain product in a user friendly way. This will be developed in the pilot and promoted in other harbour cities.

The main objective of the project is to assist consumers in making an informed choice on the energy they use. It will also enable differentiated tax rates on electricity consumption according to the carbon emissions and waste content. Partners in the project include the Municipality of Uddevalla / Uddevalla Ports & Terminals headlines AB, Uddevalla Energy AB and municipal housing companies



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