e-harbours electric

Electric Mobility

Point of departure. 10 March 2011

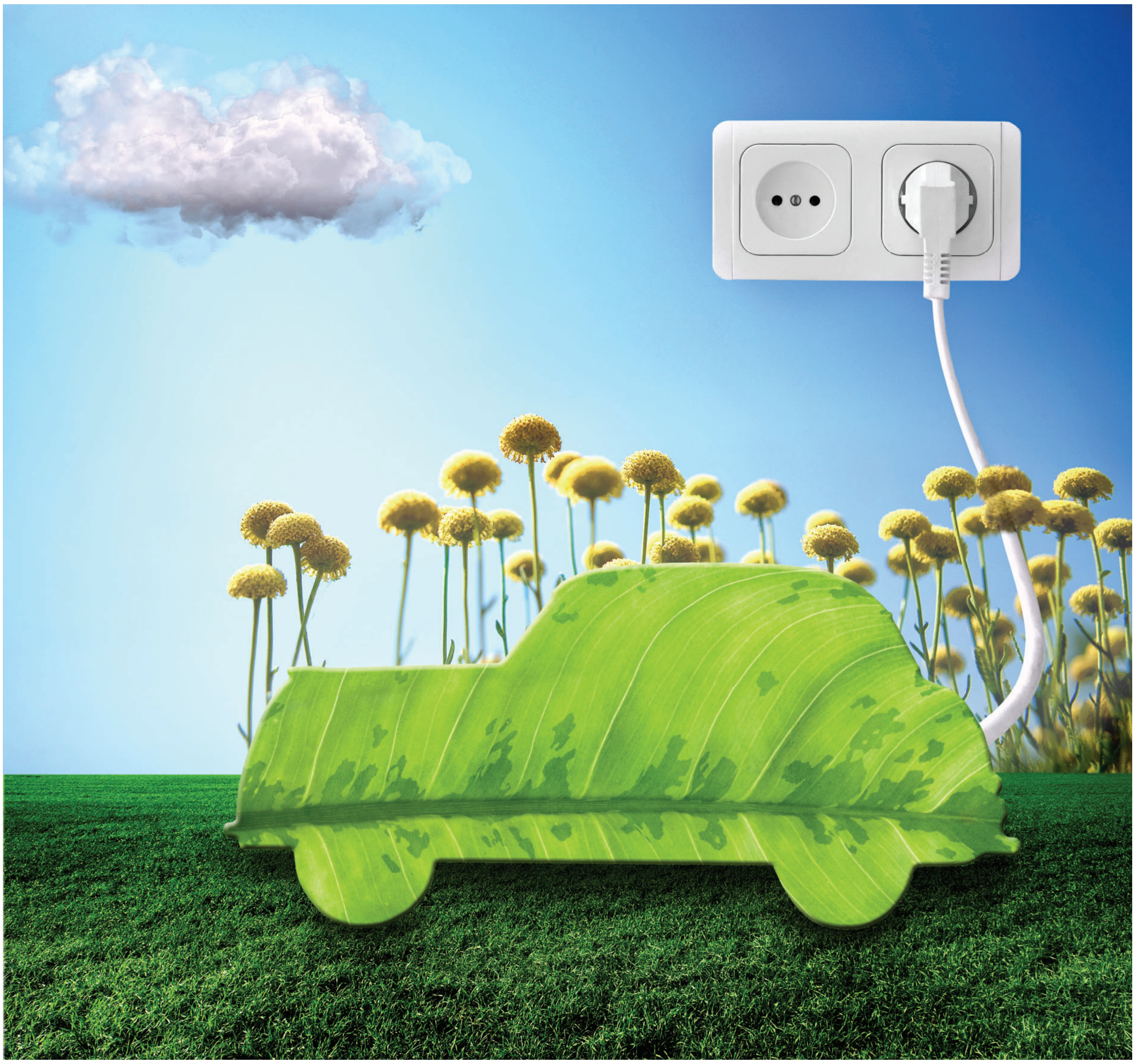
Photo: Colorbox

European Union — The European Regional Development Fund

The Interreg IVB North Sea Region Programme

Investing in the future by working together for a sustainable and competitive region

Summary



The organisations cooperating in e-harbours investigate the potential of electric transport (both on land and on water) for the harbour regions of North West Europe.
Current types of electric vehicles still have a short driving range and limited possibilities, mainly caused by the shortcomings of the batteries applied. We need batteries that perform better, at lower costs per kWh of storage. This requires a technological breakthrough. Great investments are requested in other fields, like standardisation of techniques used, building a recharging infrastructure and developing a sound business case for that recharging infrastructure. Choices have to be made from a wide range of possibilities (slow charging, fast charging, battery swapping…)
From an ecological point of view it is adamant that electric vehicles are powered by energy from renewable sources. When they use electricity from coal fuelled plants, their environmental performance is severely reduced.
Harbour zones can be considered as more or less closed systems, providing an ideal environment for research and experimentation in the field of electric mobility. The e-harbours project aims to progress the electric mobility agenda in European harbours by means of showcases in Zaanstad, Amsterdam, Malmö and the Shetland Islands.

Contents

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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_2 and other greenhouse gases is excessive, local pollution by particulate matter in some regions exceeds health norms, and noise levels are high) 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; also 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 electric mobility (both on land and on water) in the participating harbour regions.
In the first part of this paper we examine the business case for electric mobility as such. This gives us a firm footing to discuss the application and the potential benefits of electric vehicles, boats and vessels in harbour regions.

2. Electric Vehicles

This report tries to capture the current 'state of the art' in electric mobility technologies, concentrating on electric (land based) vehicles, electrically powered boats and vessels.

Types of electric vehicles:

- ***Electric vehicles (EV)****, which are fully powered by electricity from batteries that can be recharged via a connection with the electricity grid.*
- *The current generation of* ***hybrids (HEV)****, combining a conventional gasoline engine with an electric motor. The batteries that fuel the electric motor are recharged by regenerative braking or by converting energy from gasoline via the hybrid's internal combustion engine.*
- ***Plug in hybrid electric vehicles (PHEV)*** *combine the qualities (and the drawbacks) of hybrids and EVs: hybrid vehicles with a gasoline engine and an electric motor, plus a stronger battery pack, which can be recharged via a common household electric socket.*

Let us first consider the qualities and disadvantages of battery powered electric vehicles (EV). These vehicles use an electric motor for propulsion and batteries for electricity storage. The energy in the batteries drives the vehicle and powers everything else (windscreen wipers, heater, etc). [1]Batteries are recharged mainly from grid electricity. In more advanced models. the batteries can be partially recharged using energy from braking.

The advantages of battery powered electric vehicles are obvious. Electric vehicles emit nothing from the engine, so in terms of the *tank to wheel* energy use, they are local zero emission and thus far cleaner than internal combustion engines. Of course the electricity itself needs to be produced and this also causes emissions, but depending on the energy mix per country, the average CO2 emission of an EV can be much lower than the emission of a conventional vehicle. EVs are also more energy efficient than internal combustion engines (up to 3 times the engine and drive train efficiency) and current hybrids (twice as efficient), because almost all the energy is turned into propulsion and not lost as heat. The electric motors used in electric vehicles are relatively low cost. At typical electricity prices, the fuel cost per km is much less than petrol or diesel powered vehicles.

[1] Because Heating, Ventilating, and Air Conditioning (HVAC) consume a lot of energy in vehicles, some EVs use a small fossil fuel driven HVAC to heat and cool the vehicle without influencing the electrical driving range.

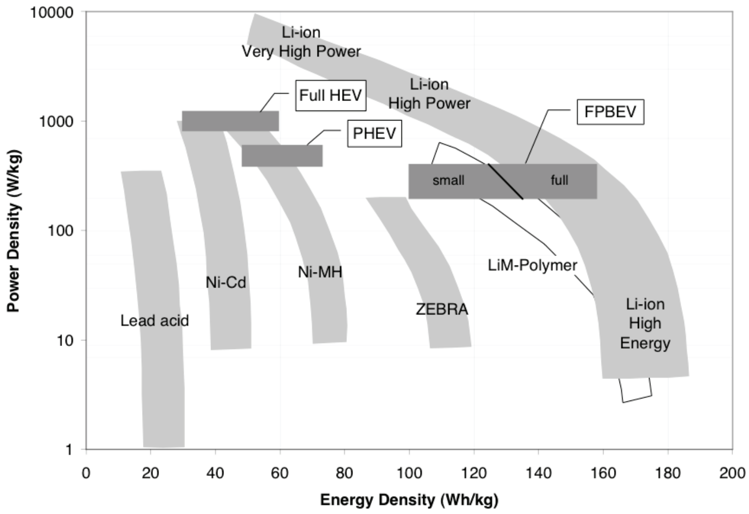
3. Battery challenges

Overall, the use of electric cars and vans is still very limited. Electric vehicles are currently too expensive compared to petrol and diesel engines and they can't travel as far. Driving an electric car with a fully charged battery is comparable to driving a conventional car with only 10 litres of gasoline on board. The electric car is plagued by battery problems. *A battery that can provide the same driving range (between 'filling up') as a diesel or petrol powered car (500km or 300km), and which would be capable of being fully 'discharged' and recharged a thousand times would cost between $35,000 -$40,000 (that is just the cost of the battery, not the car).* Such batteries would also be heavy, which would reduce the energy efficiency advantage over internal combustion engines, because the electric car would be much heavier than its carbon emitting counterpart.

You can choose a smaller battery for your car, to save on cost, but then you also have an even smaller driving range and this is already one of the bottlenecks of electric vehicles. The current generation of batteries takes too long to charge. The shorter driving range of electric vehicles wouldn't matter so much if you could charge the car or van quickly. But current EV batteries take several hours to charge, so they are of no use for long journeys. That is why the current generation of EVs are small urban run-arounds and not large family cars or white vans.

Current batteries are not especially durable, either. They have a limited number of 'charging cycles' and for the moment not enough 'real-life' data is available to estimate upfront when a battery is end-of-life. The rule in automotive is that the battery needs to be replaced once the capacity is 80% of that of a new battery - at that moment driving range is going down too much to be acceptable. Therefore the rest of the car can outlive current batteries, and because batteries are expensive, the running costs will actually be very high over the lifetime of a vehicle if the battery has to be replaced two or three times.

The next diagram compares the performance of different types of battery currently available.



The diagram shows that batteries are available in a very broad range. Making the right choice for the right application/vehicle is not easy. Some batteries can offer lots of power (sports car performance) but can't actually store lots of energy over a long period, so their range is very limited. These batteries offer good *power density*, but poor energy density for the weight.
Other batteries can store lots of energy but can't necessarily translate that into power (this type is used in the small and slow electric vans used in city centres all over Europe). These have good *energy density*, but poor power density. Developing and producing a battery which combines a good performance with a low cost is an ongoing challenge and a lot of money is put into these research activities at the moment.

Motorists want to know that they can finish their journey. Using the air conditioning or the windscreen wiper will have a small effect on the fuel efficiency and range of a petrol or diesel engine. There is no real drop off in performance between a warm summer day and a wet and cold winter day.

Batteries are sensitive to temperature, however, and using the wipers or heater drains energy direct from the battery. So the driving range of an electric car used in winter can be as much as 50% less than its range in summer. Consequently, the performance of an electric car will vary from place to place. The range and usefulness of an electric van in southern California is going to be a lot better (and the cost more competitive) than in Northern Canada.

So the limitations of the current generation of batteries mean that electric vehicles can't compete with petrol and diesel vehicles in terms of range, performance or cost.

4. The business case for hybrid cars

Conventional hybrid cars (HEVs) have a conventional internal combustion engine and an electric engine which assists with the power, and is recharged as the vehicle drives along and brakes. The battery capacity is sufficient (1kWh to 2kWh) to store the electricity generated by the engine and the brake energy recuperation, but none of today's vehicles has sufficient storage to make recharging from the grid feasible. They cannot be plugged in for reloading. HEVs account for about 3% of car sales in countries such as the USA, but the share is not rising. The problem is that these vehicles are not vastly more fuel efficient than the latest generation of diesel engines, so there is no obvious financial incentive to buy one – unless governments throw in subsidies to make hybrids more attractive.

The new generation of PHEVs is equipped with significantly more energy storage, and the batteries can be recharged via a connection to a power outlet. These vehicles offer the opportunity to travel part-time on energy provided by the grid, after each recharge (e.g. 20 km to 80 km).
They make it possible to rely more on the electricity sector for energy while retaining the driving range of today's petrol and diesel engines and they are less dependent on recharging than an EV.

Although they need less battery capacity than electric cars, plug in hybrids still require more battery capacity (x5) than their non plug in counterparts.
The batteries must be adapted to deep discharging, so will have to be more robust than current hybrid batteries. They also need to be more powerful to deliver power for bursts of acceleration. Batteries that offer both power and energy density will be more expensive than the energy dense batteries in conventional hybrids. A battery that is up to the job enough might cost $6,000, while we can expect to save $4,000 in fuel costs over the lifetime of the vehicle.
Again we have a battery problem. Currently there is no sound business case for plug in hybrids (especially compared to the latest generation of diesels) and no manufacturer currently produces PHEVs on a commercial scale.

So although demonstration vehicles abound, they are not yet state of the art, although rapidly rising oil and fuel prices might create a more competitive business case.

5. Does electric transport help the environment?

When conventional combustion engines in a harbour area are replaced by electric vehicles, this can result in a direct improvement of air quality, noise levels and other environmental parameters in the area.

On a macro level, the environmental credentials of electric transport are not necessarily clear cut. To begin with, a lot of studies show that batteries are not as green as the consumer thinks. And the energy used to power vehicles might not necessarily be particularly low carbon. The environmental performance of EVs is largely dependent on the carbon intensity of the power generation.

Obviously renewable sources of electricity are very low carbon and the best energy for powering electric vehicles. If electricity is produced by a coal fired power station, however, the case gets more complicated. While carbon emissions from electric vehicles are still lower carbon than those from internal combustion powered vehicles, the carbon emissions from plug in hybrid vehicles could potentially be higher if the electricity is generated from a coal fuelled power station. The calculation can get very intricate, when we take into account that most countries don't rely on one source of power. They have a mix of nuclear, oil, coal, gas, hydro electric and renewables. For example, the time of day when charging of electric vehicles takes place and the mix of the power produced will be a factor in determining how low carbon the electric vehicles are.

When the sales and the use of electric vehicles would rise sharply, we might have to build new power stations to meet the extra demand. If those power stations run on coal, the environmental case for electric cars is weakened further. The case for electric mobility, and EVs in particular, is clear cut when the extra demand is met by renewable sources.

Looking at the European policy (the so called 20-20-20 targets)[2], using more renewable energy in the energy supply chain is heavily stimulated, and here a synergy with electric mobility can be expected.

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[2] In 2008, the EU Heads of State and Government set a series of demanding climate and energy targets to be met by 2020, known as the "20-20-20" targets. These are:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

6. Breakthroughs required

We can conclude that there is still no clear cut business case for electric transport. This will continue to hamper the overall growth of all types of electric vehicles.

What needs to be done? Unless we realise a number of economic and technological breakthroughs the potential environmental benefits of electric transport will not be realised. But there is also a social breakthrough needed, and that could prove to be the most challenging part. User acceptance is crucial when new technologies are brought to the market. The end user will finally decide what he/she will buy and lots of requirements will have to be met simultaneously: comfort of use, flexibility, reliability, cost-effectiveness… The right policy framework should be thought out to open up the market with supporting legislation and incentives. Of course, after a certain period this market should become 'self-supporting' and should be able to run without subsidies. Finding the right business models to support the roll-out of electric vehicles will be crucial in this phase.

Apart from the social factors, the most important elements of a general approach to foster electric transport are:
- Solving the battery problem
- Standardisation of technology
- Building a recharging infrastructure
- Developing a sound business model for electric transport
- Make use of renewable energy and Smart Grid technology

A. Solving the battery problem

We need better batteries that are:

- Light
- Cheap
- Able to deliver both good power density and energy density
- Able to provide consistent performance, in all weather and temperatures
- Able to last 10-15 years and undergo 2,000- 3,000 deep discharges,
- Quickly rechargeable
- Safe
- Fully recyclable

Lithium Ion technology represents the best bet. It is likely that batteries will be developed that will allow EV and PHEV to be competitive on cost and performance, but how long these will take to come to market is far from certain.[3]
The battery cost will be critical. To really compete with diesel and petrol it must be reduced from the current estimated range of $500 to $ 800 per kilowatt hour (kWh) storage at high volume down to $300 to $400 per kWh by 2020.

B. Standardisation of technology

We need to standardise technology across manufacturers, so that as far as possible everyone uses the same *vehicle to grid* interfaces (plugs, charging protocols, etc).
Governments should act to prevent a worldwide battle about industry standards, as we have repeatedly seen in the electronics industry (for example: VHS against Betamax).

Standards for charging

The European Standardisation Organisations CEN-CENELEC and ETSI will develop a common charging system for electric cars, scooters and bicycles. The European Commission has given them a mandate to develop a European common solution for the charging of electric vehicles with the following three objectives:

- to ensure that electric vehicles can be safely charged by their drivers.
- to ensure that electric vehicle chargers (including their removable batteries) interoperate with the electricity supply points and all types of electric vehicles. This would allow users to recharge their electric vehicles anywhere in the EU by using the same charger.
- To make smart-charging possible. Smart-charging will allow users to charge vehicles at off-peak times to get the lowest price and most efficient use of energy.
- The European standard is expected to be published *medio* 2011.

[3] Factors that could hinder the development of high performance batteries include: The availability of lithium and rare earth metals, the limited number of world class battery manufacturers (will there be enough capacity to meet demand?) and the cost of current battery supply chains (high weight and low volume).

C. Building a recharging infrastructure

Most European countries estimate the need for charging infrastructure as follows :

- most charging of electric vehicles will take place at home and at work/shops (70-90%)
- the demand for public charging will be limited (10-30%), but the availability of charging points remains very important to tackle the "range anxiety" aspect,

Currently, public charging infrastructure for electric vehicles (offices, shops, on street) is limited or non-existent in many cities. As we mentioned above, electric vehicles take long to charge and there are not enough charging points.
A technology step change is required that cuts recharging times and investment is needed so that charging stations are more ubiquitous. Range can be limited as long as charging is rapid and charging stations are plentiful, and the number of opportunities to recharge the battery during the day must increase.

As well as charging batteries quicker, we should ideally have the capability to swap batteries quickly so that a car can be repowered as fast as it takes to remove one battery and replace it with another one. Also inductive charging to improve the comfort for the end user is high on the research agenda. The development of faster and easy to use charging infrastructure represents one of the key technical barriers to the greater uptake of electric vehicles.

D. Developing a sound business model for electric transport

Part of the problem is that we are not even sure of the correct business model yet or who will drive it forward.
Currently electric vehicles are expensive to buy but cheap to run. That particular 'price signal' actually encourages higher annual mileages from vehicle owners.[4]
The battery swapping approach could solve this. Under this scheme, vehicle owners would not actually own the battery, but they would be charged each time they borrowed one. In this way, the cost of the vehicle would be relatively low (without the expensive battery) and the cost of motoring would be related to how much you drive, lowering car use, traffic (and electricity demand, so that we don't have to build too many new power stations).

The battery sharing approach is quite a radical business model however, and universal agreement is required to go down that route (another item in the 'to do' column for policy makers).
Other business models will try to make use of the added value of electric vehicles as providers of energy services. By aggregating electric vehicles and by making use of their flexibility as a load (electrical storage), new business models can be developed in which electric vehicles generate a revenue by being an active player in the energy market. These studies require an insight in the energy market from economic and regulatory point of view.

[4] There is evidence that small EVs are *additional* cars rather than replacement vehicles. They are especially popular in large cities where there is differential road pricing or parking charges based on vehicle emissions. The EV is thus driven within the London Low Emission Zone and the old car is driven outside it. Theoretically this can lead to *more* car use, emissions and traffic - rather than reducing it.

E. Make use of renewable energy and Smart Grid technology

Electric vehicles can deliver a solid contribution to lowering carbon emissions if the electricity we use to recharge batteries comes from renewable sources. Ideally, we should install renewable sources such as solar panels and wind turbines at recharging stations.
In the future, we could develop Smart Grid technology so that we can use vehicle batteries to store energy from renewable sources and potentially sell it back to the grid (vehicle to grid technology: V2G).

We also need to develop smart metering and charging technology so that we can send consumers the right price signals. The role of day/night charging is a key issue to be addressed as is the role of electricity pricing (especially creating a day/night price differential for charging). This would help us manage energy demand and carbon emissions and strengthen the business case for electric vehicles.

7. Stimulating electric transport in harbour regions

How can harbour regions across North Western Europe stimulate electric transport in their area, thereby improving the environmental quality of the region and strengthening the economy? The e-harbours project has found a number of partners willing to tackle this question. In the course of this project, a number of showcases will be developed to illustrate possible solutions.

A port is potentially a closed system (with a limited number of vehicles operating across a limited spatial area) which could act as a laboratory for some of the issues we have identified in this paper. Ports could be used to trial technologies such as fast charging, battery swapping, smart metering, V2G and other smart technology (not forgetting that ports are commercial entities so there has to be a business case).

Harbour regions generally have the space and the infrastructure to make additional deployment of renewable energy possible. When renewable sources can be used to power recharging stations, the environmental benefits of electric vehicles get multiplied. This is another very important field for investigation and trial technology.

Larger ports might have sufficient vehicles (and 24 hour demand for vehicles) to justify investment in battery swapping and or fast recharge facilities. Small ports might have smaller peaked demand and a handful of vehicles. They could potentially operate a fleet of diesel vehicles and electric vehicles, with enough diesel vehicles to handle off peak demand (i.e. at night) with electric vehicles operating during the day during peak demand (and recharging at night).[5]

Apart from the conventional land based electric vehicles, ports also can make use of electric boats and vessels, and they can supply low carbon electricity to supplement diesel engines on boats sitting in harbours (so that they don't have to leave their engines running overnight.)

The contribution of e-harbours

The e-harbours project aims to progress the electric mobility agenda in European harbours though a number of showcases:

- The use of smart energy to power electric vehicle recharging points in harbour car parks (led by Zaanstad)
- Using electric boats to deliver shopping to harbour residents (Amsterdam – TBC)
- Developing charging point technology to recharge heavy harbour vehicles (Malmo)
- Looking at the potential of electric mobility (and other interventions) to reduce energy demand from small harbours (PURE Energy and Robert Gordon University)

In addition, e-harbours partners will be organising an event with a Scottish team who are developing and planning to introduce **hybrid ferries**. The event will allow the teams to share knowledge on (i) electric mobility in larger vessels and (ii) on the shore side (smart) energy management opportunities that the hybrid technology provides.

[5] Much will depend on size of port, the daily km travelled by vehicles and the power required from them (a tug master poses a more difficult technical challenge than a van or forklift).

8. Showcases

1. E-central: recharging points powered by smart energy (Zaanstad)

The project focuses on electric mobility based on renewable energies. The whole chain for green electric transport is looked upon: enhance renewable energies, conditions for uploading, choice of vehicles, their operational utilization in different processes and required conditions for spatial incorporation, juristic embedding and permissions. Involved vehicles consist of operational small trucks and cars. Main objectives of the project are to enhance the production of renewable energies, and to test and monitor the Virtual Power Plant concept in a real time situation with renewable energy, upload points and electric vehicles. Partners involved include the Municipality of Zaanstad, Truckland (maintenance of vehicles, electric mobility park/batteries performance), Construction and housing company Parteon (acquisition and utilization of vehicles) and the technical partners: Q-park, Imtech, Energy distributor Aliander, ICT companies.

2. Electric boat logistics (Amsterdam)

Within harbour cities transport of people and goods by boat is an important logistic aspect. The pilot project in Amsterdam investigates how to boost electric transport by boat, how to connect it to smart grids and how to enhance the uptake of renewable energies. Main objectives of the project are the realisation of a pilot on electrical loading facilities for water transport, optimised charging and de-charging strategies based on renewable energy, and the development of an innovative business case to concretise what smart energy grids can provide to the Amsterdam policy. Partners include the Municipality of Amsterdam, electricity network operator Aliander, Amsterdam Department (maintenance, monitoring batteries performance) and the initiative Amsterdam Smart City

3. Renewable Electric logistics in harbours (Malmö)

The question behind the Climate program is: can we maintain our economic growth while reducing out energy use? In this pilot a model is developed for a future harbour based on sustainable energies and smart grids. Main objectives of the project are to demonstrate the transition of a large conventional harbour to a 'smart harbour' using more renewable energy.

4. Energy data collection and analysis (Scalloway harbour, Shetland Islands)

While there are potential opportunities to save energy and mitigate CO2 emissions in small to medium sized North Sea harbours such as Scalloway in the Shetland Islands, little useful benchmark data on patterns of energy use are currently available. Mobile data collection meters and analytical methods are required which can record and analyse the energy profile of such harbours, so that the potential contribution of interventions such as renewables, electric vehicles, smart grids and virtual power plants can be estimated and investment prioritised accordingly.
The objective of the project is to develop smart metering technology and the associated analytical methods and models. Then other harbours in the region will be recruited to collect and analyse data on energy use. This will develop into recommendations on investment decisions regarding renewable energy, electric vehicles, smart grids, virtual power plants, etc. Partners include Scalloway Harbour, knowledge centre Pure Energy and Robert Gordon University (Aberdeen).

More information

"Technology Roadmaps - Electric and plug-in hybrid electric vehicles "
http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2156.

The Greenpeace view
http://www.greenpeace.org/raw/content/eu-unit/press-centre/reports/green-power-for-electric-cars-08-02-10.pdf
. here http://www.transportenvironment.org/Pages/clean-vehicles/

How to Avoid an Electric Shock - Electric Cars: from Hype
to Reality.
http://www.sustainable-mobility.org/ressources-documentaires/how-to-avoid-an-electric-shock.html

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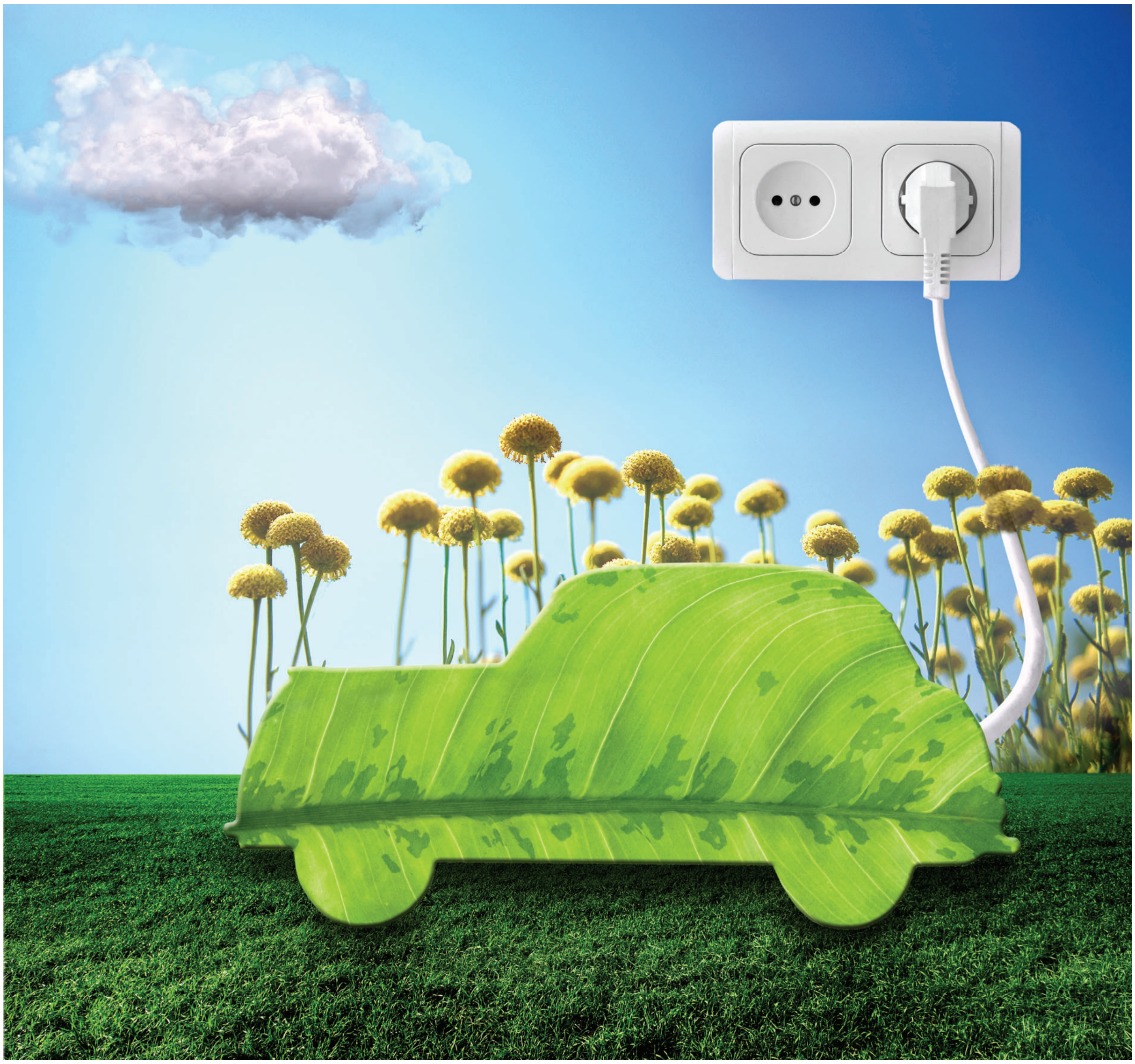
Summary



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Hochschule für Angewandte Wissenschaften Hamburg – Hamburg University of Applied Sciences
pure ENERGY CENTRE
City of Amsterdam
Malmö stad
UDDEVALLA ENERGI
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Zaanstad top van de Randstad