Report on the In-depth Identification of Emerging Technologies

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1 Introduction

Increasing energy efficiency always was and still is closely correlated with the development of new technologies. Therefore, if it is aimed to further enhance energy efficiency, considerable and targeted investment in innovative technologies is a major factor of success.

First and foremost this is the responsibility of enterprises. However, according to empirical evidence the coincidence of the enterprises' technology-push with a correspondent market-pull by the consumers increases the success of an emerging technology significantly. Thus, due to the market power of the purchasing activities of public authorities, sustainable public procurement plays an important role in the development of highly energy efficient technologies by closing the gap between sustainable product development and sustainable consumption.

Within the scope of SMART SPP, highly energy efficient technologies refer to products using a technology that is in the latest stage of development (R&D process) or to a product that is developed but has not reached the market yet. The technologies have to be innovative in the sense that a similar product using this technology has not been available before. Highly energy efficient means that in comparison to other similar products using this technology the energy efficiency rate is significantly higher.

However, it has to be considered that a highly energy efficient technology is not environmentally friendly ipso facto. This can only be ensured by looking at the entire life cycle of a product, so as to avoid a situation where environmental relief during the service life of a product is counteracted by additional environmental pressure during its manufacturing phase or at the end of its service life. Such a life cycle thinking approach forms the essence of an appropriate monitoring during the development of emerging technologies.

Against this background, SMART SPP focused the in-depth identification of suitable emerging technologies on the following product groups, which were considered to be most relevant in terms of increasing energy efficiency:

- Construction services and equipment;
- Office and ICT products;
- Public transport and other vehicles;
- Lighting equipment.

2 Methodology

The identification of the best suited emerging technologies was tied up to the knowledge gained from other European projects such as the Cost and Benefits of Green Public Procurement (GPP) Project undertaken for the European Commission in 2007, the EC GPP training toolkit or the regular information exchange taking place within the Procura+ Sustainable Procurement Campaign (www.procuraplus.org). Additional information was assessed by reviewing business and manufacturers, telephone dialogues with key developers in respective business sectors as well as extensive literature and internet research. Another information pool was the Öko-Institut's EcoTopTen project, which continuously screens innovations within the ten environmentally most relevant product groups in order to compile product rankings for end consumers. Furthermore, the identification of emerging technologies was also the main goal of a Procura+ expert seminar held in November 2008 in Birmingham, United Kingdom. Besides expert sessions on pre-procurementand smarter engagement with the market in general, there was also in-depth analysis of cutting-edge developments in heating/cooling through renewable energy resources, electric vehicles with green energy resources and LED lighting and ICT equipment.

Based on the evaluation of existing information regarding current R&D activities as well as sustainable procurement projects and conferences a document was developed in order to help the SMART SPP public authorities (Barcelona, Cascais, ESPO, Global to Local, Kolding and Torres Vedras) to identify in which field or type of technology they want to start a pre-procurement, taking into consideration the following emerging technologies:

- RES heating: heating of buildings with renewable energy sources;
- RES Cooling: cooling with renewable energy sources (RES) technologically based on an adsorption chiller;
- District Heating: system for distributing heat generated in a centralised location for space heating and water heating;
- Combined heat and power plants (CHP) below 2 MW: small scale combined production of heat and power with an overall annual efficiency of 80-90% for power and heat production;
- Vacuum Insulated Panels (VIP): insulation product that combines high thermal resistance with a relatively thin panel;

- Solid state computers: computers with a solid-state drive (SSD) that use solid-state memory to store persistent data;
- Thin Clients: computers within a client-server architecture network which focus on conveying input and output between the user and the remote server;
- Small and highly efficient vehicles: vehicles characterised by a lightweight mode of construction and / or a power rating being as low as possible;
- Electric / hybrid vehicles: vehicles only with electric engine or plug-in hybrids with lithium-ion batteries and stronger electric engines;
- Electric / hybrid vehicles: vehicles only with electric engine or plug-in hybrids with lithium-ion batteries and stronger electric engines;
- LED Lighting: lighting technologically based on light emitting diode (LED) or Organic Light Emitting Diodes (OLED) enabling energy savings potential of 80% and above;
- Solar street lighting: lighting systems characterised by a solar panel absorbing the suns' rays and converting them to electricity;
- Light tubes: lighting systems that transport or distribute natural light inside buildings.

Further explanation of the different technologies as well as possible applications and suppliers was given in the document prepared by Öko-Institut (cf. attachment to this report). Besides the proposed emerging technologies the public authorities were invited to indicate further technological innovations, which they considered to be suitable for the SMART SPP project.

The document also included a matrix that the public authorities should fill in, in order to evaluate with more accurate information with whom in the organisation and on what technology start working for the pre-procurement giving the timeframe of the project, the political support and involvement of relevant departments. The information was requested in detail can be found in Annex 1.

3 Results of the analysed demand of the participating public authorities

Based on the procurement authorities' feedback regarding the questionnaire as well as the further bilateral information gathering the following findings were made. They are presented in accordance with the above mentioned four product groups.

3.1 Construction services and equipment

Regarding construction services and equipment the Portuguese city of Torres Vedras showed general interest in district heating. However, no previous experience is available within the public authority, as district heating is not very common in Portugal at current state. Also the commitment of the local political decision-makers is regarded to be only moderate.

In Portugal also the city of Cascais has general interest in this product group; however it was not specified if the focus should be on RES cooling/heating or rather on insulation. Like in Torres Vedras, concrete examples for possible applications could not be provided.

Barcelona in Spain is currently exploring the possibilities regarding RES heating and especially RES cooling. Regarding the latter, Barcelona is following the idea to convert already existing solar heating systems (thermal solar panels) into cooling systems via two different absorption technologies. Within this context it would be helpful for Barcelona to find alliances. However, more precise information e.g. concerning concrete applications, procurement volume is currently not available as the tender is not previewed before 2010/2011.

The Eastern Shires Purchasing Organisation (ESPO) also showed interest in RES heating/cooling technologies requesting for further information especially on products which can act as fuel (e.g. biomass fuel pellets). However, other energy inputs, e.g. geothermal energy, might also be suitable as the investigations on this technology sector are still at an early stage.

Kolding (Denmark) is interested to follow experiences of other municipalities that would look into RES cooling, whereas special interest was shown for the SorTech solar-chiller solution. According to the procurement experts, this emerging technology would be especially interesting for modern office buildings. Both energy savings and political commitment is estimated to be high, whereas the cost-savings potential is expected to be moderate.

District heating is also interesting for Kolding, but it is necessary to make it more effective for low energy housing.

When summarising the assessment of this product group, general interest could be observed within all procurement authorities. The already existing experience, however, as well as the willingness to undertake concrete initiative and lead management is considered to be rather low.

3.2 Public transport and other vehicles

The assessment of emerging technologies in this product group comprised small and highly efficient as well as electric and hybrid vehicles. Most of the public authorities interviewed already had contact to hybrid technology or even purchased a small number of hybrid cars like the Toyota Prius.

For example, 100 hybrid cars (Toyota Prius) were already procured in Cascais showing the high commitment of the local decision-makers. Political commitment regarding sustainable mobility solutions is comparably high in Torres Vedras, although the technological approach is not defined yet. However, also in Torres Vedras two hybrid cars were already purchased and investments on hydrogen and the purchase of two passenger busses and are envisaged for 2009.

Barcelona also showed interest in this product group. Concrete applications are electric vehicles in combination with charging points. The procurement volume was quantified with ten charging points for electric cars until 2010 and possibly 150 until 2011. Pay-back time is regarded to be no issue for decision-making, which symbolises the demonstrative character and prestige aspects of sustainable mobility solutions for this city. Additionally, the City of Barcelona already conducted a strength-weakness-opportunities-threats analysis for innovative electric and hybrid vehicles.

The City of Barcelona furthermore expressed special interest in different types of battery technology and different solutions for electrical charging points. Buying electric / hybrid cars in bulk with other procurement authorities was considered unfeasible due to organisation circumstances.

ESPO is particularly interested in hybrid electric vehicles in the context of a foreseen contract volume of 1000 vehicles. In contrast to Barcelona, buying in bulk with other procurement authorities was considered possible.

The city of Kolding, however, plans procuring electric vehicles in context of another project.

Compared to the building sector, emerging technologies in the mobility sector already receive much higher attention among most of the project's procurement authorities. Furthermore, with first experienced data existing, a window of opportunity seems to be existent especially regarding electric/hybrid vehicles. Nevertheless, it has to be pointed out that the sustainability leverage effect of emerging technologies like electric and hybrid cars strongly depends on the electricity mix. Simply procuring electric or hybrid vehicles and using the status quo electricity mix (often provided by fossil fuels) is neither exceptionally innovative nor environmentally-friendly. Additionally, the vehicle size also has to be chosen carefully as the size might greatly influence the energy efficiency and therefore the environmental impact of the vehicle. Furthermore, it has to be kept in mind that the implementation of these new driving technologies entails a renovation of the whole supply system, including filling stations/charging points and specialised garages (cf. section 5).

3.3 Office and ICT products

The identification of emerging technologies in the field of office and ICT products was highlighted on solid state computers and thin clients, both promising a significant specific energy savings potential.

One procurement authority (ESPO) showed interest in this product group. When investigating the reasons for this lack of interest, all other procurement authorities referred to the very limited influence on the technical specifications of office and ICT products. The reason for this phenomenon can be found in the co-operation with large service providers who define the technological standards. Thus, when it is aimed to enhance pre-procurement within the office and ICT sector, primary contact should not be the procurement authorities but rather their service providers. ESPO, however, expressed interest in solid state computers and pointed at the possibility to influence procurement in this sector via large volumes. Additionally ESPO indicated that pre-procurement is difficult because suppliers in the ICT sector particularly tend to stay with already known products and ICT therefore is a very conservative sector for public authorities.

3.4 Lighting equipment

When evaluating emerging technologies in the lighting sector, response was met at all public authorities of the SMART SPP project; throughout high commitment of the political decision-makers could be observed. Among the proposed emerging technologies, LED lighting is the most prominent.

Regarding concrete applications, Kolding favours office lighting (room lighting, desk lighting) across its municipal buildings. Baseline technology is mostly the fluorescent light tube.

Barcelona would like to focus on traffic lights and street lighting, whereas in Torres Vedras and Cascais the technology is not defined yet. Also Global to Local (UK), the national co-ordinator of SMART SPP in the UK, sets a high priority on LED lighting and thus has prepared an overview paper comprising extensive information regarding the technology and possible applications.

Information on concrete procurement volumes, however, was only provided by Kolding: Within this city 45,600 light tubes are waiting for substitution by a more energy efficient technology. Also regarding the implementation of LED lighting within the time scale of the SMART SPP project Kolding offers a highly promising window of opportunity. As the city's 2-years framework contract / tendering for lighting services will be renewed in April 2009, the following contract renewal will take place in April 2011.

Less advantageous contractual circumstances could be found in Barcelona, where a public lighting tender is envisaged for 2009 and will last for four years. Unfortunately, the other procurement authorities were not able to provide precise information on that aspect yet.

Kolding could also provide important constraints for a successful implementation of LED lighting. According to their perspective, quick and easy exchange and compatibility to existing light casing is a major factor of success. Furthermore, the pay-back time should be lower than five years.

According to feedback from Barcelona, the guaranteed service life in working conditions is even more relevant than the pay-back time for the procurement decision.

For the Portuguese cities of Torres Vedras and Cascais an important constraint for the procurement of LED lighting is the existing concession contract with the national monopolistic electric energy provider EDP. However, Portuguese public authorities mentioned that this monopoly situation might be overcome by LED companies which provide extended guarantees and special maintenance offers.

Based on the detailed feedback from Kolding regarding LED lighting the next steps towards the successful procurement of innovative lighting technologies should address the following aspects:

1) Assess of current energy consumption; clarification needs regarding the assumptions to be made (e.g. using prEN 15193);

2) Drawing up targets compared to the current lighting system (e.g. 20% less energy consumption);

3) Select a demonstration object (defined space / room / building necessary in order to enable joint procurement with other procurement authorities);

4) Define general conditions such as (wall) reflection, window surface, orientation, daylight, shade, light intensity requirements per purpose unit;

5) Provide Know-how for the integration of energy efficient lighting into old buildings (expected to be more difficult than into new buildings);

6) Collect information on guaranteed average service life and maintenance intensity of emerging technology

7) Gain information on pay-back time of the emerging technology;

8) Obtain guidelines for the use of specific pre-procurement procedures, especially looking into PIN, Competitive Dialogue and pre-commercial procurement

9) Incorporate R&D costs into the general Life Cycle Costing balance.

These needs were processed within the in-depth analysis and characterisation of innovative lighting solutions (cf. following chapter).

4 In-depth characterisation of innovative lighting solutions

4.1 LED technology

The first section of this chapter concentrates on the technology of Light Emitting Diodes (LED) for three different applications. LED technology is already common for applications like vehicle headlights, exit signs and decorative lighting panels. However, in the following, only the applications traffic lights, street lighting and office lighting are depicted, as these applications represent the main interest of public authorities. As the energy saving potential of LED lighting is often stated to be up to 90 percent, this technology has caught great interest by public authorities.

4.1.1 Description of the technology

Light Emitting Diodes are electronic light sources. In contrast to other lighting technologies, where vacuum or gas tubes are the basis of the light emitting process, in LED technology, light is emitted from a solid object. Therefore, LED lighting technology is also called 'solid state lighting'.

LEDs consist of semiconductor chips which produce light by the recombination of charge carrier pairs within a semi-conductor[1]. In more detail, electrons recombine with holes, and energy (=light) is released when the diode is switched on. This effect is called "electroluminescence" and LEDs are henceforth classified as electroluminescence emitters.

The most common semi-conductors used for LEDs comprise elements of the third or fifth group of the periodic table (so called III/V-semi-conductors) as these elements offer the most effective recombination. Examples for such elements are gallium phosphate (GaP) and indium gallium nitride (InGaN).

The conductivity of semi-conductors rises with increasing temperature. However, the efficiency of LEDs decreases with increasing temperature. Therefore, LEDs are most efficient when the surrounding temperature is low. However, this temperature dependence does not mean that

[1] A semi-conductor is a material that has electrical conductivity between those of a conductor and an insulator.

LED technology is not suitable for outdoor application. Manufacturers provide LEDs which have a wide operating temperature range (e.g. Carmanah EvergGEN 1500 series: -30° to 50°C).

Generally, the colour of the emitted light is determined by the energy gap of the semi-conductor. Hence, no colour filters are needed in order to produce coloured light. However, the production of white light has formerly been a challenge. Currently, there are two options to generate white light with LED technology: either several coloured LED chips are combined within one casing (RGB Red Green Blue LEDs) or a blue LED is equipped with a luminous coat which converts the blue into white light.

LEDs are also known for their great colour rendering which is indicated by the Colour Rendering Index (CRI; R_a). For office lighting a CRI value of >80 is recommended (see DIN EN 12464-1). This value is already acquired by white LEDs. Furthermore the colour temperature (also called “luminous colour”), measured in Kelvin (K), is used as indicator to define “agreeable / pleasant” light. Incandescent lamps usually have a colour temperature of 2200-3400 K and daylight, which typically contains a great blue ratio, possesses a colour temperature above 5000 K. Warm white LEDs on average provide 3000-4000 K, however white LEDs can also easily match daylight colour temperatures.

LED technology represents a new light source with different operating characteristics than incandescent lamps and discharge lamps. LED lamps, for instance, turn on and off instantly and do not require any pre-heating time. Furthermore, they are very shock resistant and therefore represent a reliable and robust lighting technology.

In general, the advantages and disadvantages of this lighting technology (for all sorts of applications) can be summarised as indicated in the following table.

Table 1: Advantages and disadvantages of LED technology

Advantages of LED technology[2]	Disadvantages of LED technology
High efficiency, low power consumption (mainly 20 mA, for some high performance LEDs, 350 mA is required) and low operating voltage (2-4V)	Relatively high price
Increased lifetime (depending on the application more than 100 000 h)	Voltage sensitivity (resistors or current regulated power supplies are required)
Slow failure (LEDs fail by dimming over time but do not burn out or stop emitting light abruptly)	Blue pollution (only valid for cool-white LEDs which can cause more light pollution than e.g. high pressure lamps
Rapid on/off time and no disadvantage when using for cycling applications	Temperature dependence (ambient temperature greatly influences the LEDs' performance)
Small size (typically smaller than 2 mm)	
Lower heat development	
Shock resistant (in contrast to discharge and incandescent lamps LEDs)	
Mercury free technology (in contrast to discharge lamps)	

Additionally, LED technology offers the advantages of causing neither maintenance nor cleaning costs. Further advantages become obvious regarding the specific application, e.g. no impact on insect orientation or reduced air conditioning costs because of the reduced heat radiation. These advantages are therefore explained for each application later on.

2 All advantages and disadvantages are given in comparison to discharge lamps.

4.1.2 LED solutions for traffic lights

Traffic lights represent one application of LED technology which is already relatively well established. Additionally to the advantages given in table 1, advantages compared to current technologies, e.g. high pressure sodium discharge lamps, are:

- No phantom lights;
- Uniform luminance density;
- Optimal visibility (even when sunlight is shining at the traffic light);
- No maintenance costs,

Product availability and timeframe for further R&D in the next 2-3 years

LED technology for traffic lights is already available on the market. Standard 100, 200 and 300 mm diameter light signal units are easily purchasable. Currently, this technology is already the leading and best available technology for construction zone traffic lights, as those are highly dependent on a low power consumption and good visibility. Furthermore, LED experts[3] foresee LED technology to become the leading technology for all traffic light applications.

In general, most of the discharge traffic light lamps can easily be replaced by LED units. Therefore, replacement of other lamp technology with LED is feasible.

Several manufacturers also indicated selling LED traffic light units since almost 10 years and that these units are very reliable. Therefore, the market demand is corresponding. For the next 2–3 years of LED technology in traffic lights, most manufacturers and experts foresee changes because of further increase of light yield and an advanced dissemination of dimmable light units. Some manufacturers also envisage traffic lights which adapt to weather and ambient lighting conditions such as rain or low standing sun. However, these latter developments of traffic lights are not connected to LED technology directly but rather to the automatic control system of traffic lights.

[3] Manufacturers information of “Preiser Mess-, Steuer- und Regel-Technik” and “Royer Signal” [Personal communication with manufacturers].

Current and estimated future energy performance/consumption in relation to the current best available technology

The energy savings of LED traffic lights compared to discharge lamps are **estimated 70%**. However, so far no research results are available e.g. concerning the extremely long lifetime of LEDs.

Examples for suppliers and manufacturers of LED traffic lights

- ROYER Signaltechnik (www.royersignal.de);
- Various Korean, Chinese manufacturers, such as Korea Electric Traffic Co. Ltd. and Shenzhen Coship Electronics Co. Ltd;

Functional and technical specifications of LED technology in traffic lighting

Table 2: Functional and technical specifications of LED technology in 100, 200 and 300 diameter units

Specification	100 mm diameter unit	200 mm diameter unit	300 mm diameter unit
Supply voltage	DC: 24 V AC: 230 V	DC: 12 V AC/DC: 24 V AC: 40 V or 230 V (optional 110 V)	DC: 12 V AC/DC: 40 V AC: 40V or 230V (optional 110 V)
Wattage	3-6 W	~10 W	~10 W
Lifetime	50 000–100 000 h	50 000–100 000 h	50 000–100 000 h
Price per module (including all 3 colours)t	350–400 €	~ 550 €	~ 750 €

It is indicated that the price and wattage for red LED units differs from orange and green. Currently manufacturers give the usual 2 years guarantee although LED traffic lights outlive a much longer time period.

Information on ongoing research and development projects

In Germany, the city of Aachen has a pioneer position of LED application in traffic lights. In 2005, a 20-year-contract was signed and 111 traffic lights were replaced with LED technology. The total investment was 1.57 Mio € and the savings per year are estimated at 215,000 €.

4.1.3 LED solutions for street lighting

Street lighting includes different applications. It is important to consider the different functional requirements connected to these applications. Therefore, a definition of the specific application in street lighting is required. One definition which is used for street lighting in the preparatory studies of EuP (Energy using Products)[4] is the following:

“Traffic signs and road signalisation products: their function is not “to provide good visibility…during hours of darkness” and they consequently have different characteristics from street lighting. (…)These categories with the same lighting levels and more corresponding with the classes used in European statistics for road lengths are defined hereafter:

1. Category F “fast traffic” with fast motorized traffic use only, having only luminance requirements (cd/m²). Also corresponding to classes ME1 to ME5 or MEW1 to MEW5 for new installations.

2. Category M “mixed traffic” with motorized traffic, slow moving vehicles, and possibly cyclists and pedestrians with only luminance requirements (cd/m²). Also corresponding to classes ME2 to ME5 or MEW2 to MEW5 for new installations.

3. Category S “slow traffic” for mainly urban and pedestrian areas, with illuminance requirements only (lx). Corresponding to classes CE0 to CE5, S1 to S6 and ES, EV and A classes for new installations. (…)”

Within the report of the EuP Preparatory Studies Lot 9 (published January 2007) LED technology was still assessed as the best not yet available technology (BNAT). However, it is important to note that the main reason for this appraisal was the lack of availability – not a lack of technological characteristics of LED technology itself. Since this study, LED technology continuously progressed and manufacturers emerged.

4 Cf. EuP Preparatory Studies Lot 9 „Street lighting“ (http://www.eup-network.de/product-groups/preparatory-studies/)

Product availability and timeframe for further R&D in the next 2-3 years

Street lighting is one of the most developing application sectors for LED technology. In general LED technology is already available for small roads in urban and pedestrian areas (category S). The replacement of existing street lamps with LED lamps is still difficult and only few manufacturers offer LED modules. Currently, most manufacturers only sell complete systems including the pole. However, some manufacturers and LED experts are convinced that replacement-modules will be available soon as appropriate research is already being carried out. These replacement-modules will facilitate the exchange of discharge lamp technology with LED technology and furthermore ensure that replacement of these LED modules will also be possible after 10 years of utilisation.

Furthermore, some manufacturers combine LED technology with solar technology for street lights (e.g. Carmanah). This combination of both technologies presents another advantage for further energy and cost savings. Currently these street lights are not suitable for large streets and roads (category F and M) due to inefficient lumen output. However, the improvement of the lighting efficacy (lumen output) is one of the main research goals.

Current and estimated future energy performance/consumption in relation to the current best available technology

The estimation of the energy saving potential of LED technology for street lighting strongly depends on the existing technology in a community or city. Street lights can be furnished with mercury-containing high pressure lamps, sodium high pressure lamps or compact fluorescent lamps. Therefore, only an estimation of **at least 30% energy saving** can be given.

Another challenge in this application is the improvement of radiation characteristics. Currently, LED street lights are not suitable for large streets as the current characteristics lead to unpleasant blinding effects which influence the road safety.

Main suppliers and manufacturers of the products/services

Examples for LED specialists are:

- Joliet (**www.joliet-europe.com**);
- LEDTraffic, DK (**www.ledtraffic.dk**);
- LED Lite Power , UK (**www.ledlite-power.co.uk/streetlighting.php**);
- Carmanah, CA (**www.carmanah.com**).

Suppliers, which also manufacture other lamp technology than LED:

- PHILIPS;
- OSRAM.

Functional and technical specifications of LED technology in street lighting

Table 3: Functional and technical specifications of LED technology in street lighting

Specification	LED technology in street lighting
Wattage	35 - max 200 W [in comparison: sodium high pressure lamps 70 - 250 W]
Lifetime	50 000 – 75 000 h
Amortisation time	17 months to 5 years (depending on application)
Guarantee	1 – 3 years (depending on manufacturer)
Price (for whole system)	> 400 €

As maintenance is greatly reduced or even not required at all the elevated price of LED street lights needs to be put into perspective.

Information on ongoing research and development projects and reports

In August 2003 the final report on the “Technology Assessment of LED for Street and Parking Lot Lighting Applications” prepared for the San Diego Regional Energy Office was published[5]. As this report aimed to identify “commercial available products for LED lighting of street and parking lots” public authorities may find the structure and methods section of this report very helpful. Especially the chapter “Implementation Strategy” gives an informative example on how communities can implement LED technology for street lighting.

A pioneer program for LED technology in lighting is the LED City Initiative. (http://www.ledcity.org/). This initiative aims to “accelerate the deployment of LED lighting for cities worldwide”. What started in December 2006 in the US city Raleigh, NC, shortly afterwards encouraged the Canadian city Toronto to join. Until today already many other cities worldwide expressed their interest in joining, too. The initiative offers interested municipalities to get into contact with leading manufacturers, such as the US manufacturer CREE, science groups and cities already testing LED technology.

In Europe several cities, e.g. Aachen and Darmstadt in Germany, Seville in Spain and Rotterdam in the Netherlands, already replaced some of their high pressure sodium street lights with LEDs. Switzerland also experiences first replacement tests (e.g. in Igis / Landquart).

4.1.4 LED solutions for office lighting

Nowadays, LED lamps for domestic lighting are more and more getting into the lighting market. These lamps can partly also be used in office lighting applications, e.g. LED tubes which can replace fluorescent tubes as T8 and T12. They are assessed as highly energy efficient and their long lifetime (up to 100,000 h) making them attractive although prices are still very elevated.

[5] Tetra Tech EM inc.; San Diego, CA (2003) Technology Assessment of Light Emitting Diodes (LED) for Street and Parking Lot Lighting Application, San Diego Regional Energy Office, Public Agency Energy Partnership Program

Product availability and timeframe for further R&D in the next 2-3 years

The availability of retrofit LED lamps (lamps which contain a “base / socket”) on the market is rapidly growing – so is the demand. Retrofit LEDs can be applied to replace compact fluorescence lamps, e.g. E 27, and quite a few models are already on the market.

The application of LED technology for “tube lamps” is also starting to grow currently. In order to replace fluorescent tubes like T8 and T12 the electronic ballast of the lamps has to be bypassed or removed in most cases because LED technology does not require them any more. Although the replacement is technically feasible one possible disadvantage of LED tubes has to be overcome: the angle of radiation (lighting angle) of LED technology is 60 - 120°; in contrast fluorescence tubes provide a 360° angle of radiation. Examples for manufacturers of LED tubes with a 120° angle of radiation are the German manufacturers Innowave, Lucano LED and LEDNED.

However, the main disadvantage for LED technology in office lighting for both lamp types is still the relatively low lumen output. In January 2009 a CALiPER Benchmark Report for the US Department of Energy was published[6]. This report contains the results of a comparison of LED replacement tube lamps for fluorescent T8 and T12 lamps. According to these data, the efficacy (lm/W) of LED tubes is still not comparable to fluorescent tubes. T8 and T12 fluorescent lamps showed 80 - 96 lm/W while LED replacement tubes reached 52 lm/W at maximum. Additionally, this report contains an overview of the progressive increase in efficacy in Solid State Lighting, LEDs between 2007 and 2009. Although the data for this report was collected on the American market, the reflected mean increase of around 15 lm/w within less than two years can also be used as an indicator of the European market. Hence it follows, that a further increase of LED technology application (for replacement of fluorescent lamps) is strongly connected to further research and development on the efficacy of LEDs.

One of the most important advantages of LED technology in office lighting is the flicker free lighting. Additionally, the air-conditioning costs for offices can be reduced due to LED lighting as this technology generates less heat than fluorescent technology.

6 Cf. CALiPER Benchmark Report (2009) “Performance of T12 and T8 Fluorescent Lamps and Troffers and LED Linear Replacement Lamps”.

Current and estimated future energy performance/consumption in relation to the current best available technology

Due to the great variety of LED products already available on the market it has to indicated, that the quality of the products differ greatly. Currently no report or test result on the actual energy saving potential of LED technology is available, however manufacturers and suppliers advertise with up to 90% savings of energy consumption. The savings in energy consumption result in relatively short pay-back times. According to Innowave, the pay-back time of LED tubes (length: 150 cm) only accounts for 2.5 years for most purposes.[7] This period can decrease even below one year if the application requires a twenty-four-seven service.

Main suppliers and manufacturers of the products/services

The following table lists several LED manufacturers for three applications in office lighting. This list is only showing an extract of all manufacturers currently on the market.

Table 4: Manufacturers of retrofit LEDs, LED tubes and LED desk lamps

Manufacturers of retrofit LED	Manufacturers of LED tubes	Manufacturers of LED desk lamps (*)
ATG Electronics	ATG Electronics	Paulmann
Boca Flasher	CJ-Light	Reydéns
DeltaLux	ATP Canada	CJ-Light
Dialight	Ever-LED	
Innowave	Innowave	
EBT	IVL Lammert Trading	
LEDtronics	Ronfell	
Lightfresh	SinoStar Lighting	
Siemens	Lightfresh	
Philips	Lucano LED	
Osram		

(* Reference: Swiss S.A.F.E study, cf. http://www.topten.ch/uploads/images/download-files/LED-Test_Messbericht_130109.pdf)

[7] Cf. http://www.energiespar-lichttechnik.de/html/innowave.html

Functional and technical specifications on office lighting

Table 5 Technical specification for retrofit LED lamps

Specification	LED technology in office lighting (retrofit lamps)
Wattage / Power E27 (230 V)	8 W [halogen lamp 40W]
Wattage / Power GU 10 (230 V)	4-5 W [halogen lamp 20W]
Wattage / Power GU 5.3 (12 V)	4 W [halogen lamp 20W]

Price and lumen output differ enormously between different models and manufacturers. Additionally, retrofit LEDs are estimated to undergo a rapid price reduction within the next years. Specifications have therefore not been included.

Information on ongoing research and development projects

Currently there is no pioneer project or frontrunner research for LED technology in office lighting known. Research Institutes for LED technology in general are:

- TU-Darmstadt, Germany (http://www.emk.tu-darmstadt.de/institut/fachgebiete/lt/forschung/arbeitsgebiete/);
- Lighting Research Institute NY, USA (http://www.lrc.rpi.edu/);
- Taiwan Industrial Technology Research Institute (ITRI) (http://www.itri.org.tw/eng/Research/Focus-Area/focus-sub-area-category.asp?RootNodeId=0301&NodeId=03012&FieldCD=02500).

4.2 OLED technology

OLEDs are organic LEDs. Their electroluminescent layer is composed of a film of organic compounds, mostly polymers. This technology is mainly foreseen to be applied in displays because OLEDs have the great advantage that they do not require backlight and are therefore much thinner as e.g. LCD. However, the major disadvantage of OLEDs is their low lifetime as well as a reduced lumen output (in laboratory: 50 lm/W only[8]). Currently, only very few manufacturers already sell OLED technology. One example is OSRAM, which in a press release in 2008 presented a limited edition table light applying this technology (http://www.osram-os.com/osram_os/EN/Press/Press_Releases/Organic_LED/OLED-lighting-project-Ingo-Maurer.jsp).

The European Project “OLED100.EU” (http://www.oled100.eu/homepage.asp) is a pioneer project funded under the Seventh Framework Program (FWP) and coordinated by a PHILIPS scientist. Its “overall goal of OLED100.eu is to develop all the necessary technologies forming the basis for efficient OLED applications for the general lighting industry in Europe”[9]. The five main objectives of this project are:

- Increase power efficacy (100 lm/W);
- Increase lifetime (100.000 h);
- Apply technology to a large area (100x100 cm^2);
- Reduce the price (100 Euro/m^2) and
- Development of a system integration / standardization / application.

These objectives point out the current and future research directions and also show the main disadvantages of OLED technology as up today.

8 Cf. Wikipedia (State of affair March 2009).
9 Cf. Project website www.OLED100.EU.

5 In-depth characterisation of innovative electric and hybrid vehicles

Electric vehicles, in principal, are nothing new. First applications were already introduced on the market more than 100 years ago. Especially after the “oil shocks” in die 1970ies and 1980ies the need for electric drive was discussed. However, the solutions that entered the market were often not sufficiently mature and could only survive in market niches. Major problems were technological limitations in the field electrical energy storage.

Due to intensifying debate on climate change and innovations in the battery and storage technology, the electric drive re-entered the debate regarding the best propulsion system for road transport in the future. As one of its important advantages is the (potentially) high efficiency, the electric drive is expected to play an important future role among the different possible propulsion systems for vehicles.

Within the following sections, a variety of the most important technological solutions in terms of electric road mobility are characterised in detail and assessed against the background of the objectives of this project. These are in particular (pure) electric vehicles, hybrid electric vehicles and plug-in electric vehicles.

5.1 Electric Vehicles

An electric vehicle (EV) is defined as “any autonomous road vehicle exclusively with an electric drive, and without any onboard electric generation capability”[10]. This implies that an EV does not contain any fuel cell that converts chemical energy into chemical energy. Therefore, all EVs need to be recharged after having reached the maximum range.

The worldwide EV fleet is currently (2007) estimated with 300,000 units, whereas approximately 55,000 are located in the US. In Europe, major EV clusters can be found in the Netherlands (30,000 units) and in Switzerland (23,000 units)[11].

10 Cf. International Energy Agency; Hybrid and electric vehicles, Annual report of the Executive Committee and Annex I over 2007, March 2008.

11 Cf. International Energy Agency; Hybrid and electric vehicles, Annual report of the Executive Committee and Annex I over 2007, March 2008.

Important manufacturers are firms like Nice Cars (GB) and Th!ink (NO). The current performance level of EV is exemplified on the basis of Nice Cars´ EV called "Ze-O", which entered the market in 2008[12]:

- 4 seats;
- Electric engine with 15 kW;
- Lithium ion storage unit;
- Maximum speed 80 km/h;
- Maximum range 100 km;
- Electricity consumption ca. 18 kWh/100 km;
- Price: 17,700 €.

Further information regarding existing and near-term available electric vehicles can be found in the document "Electric Vehicles – a briefing paper", which has been composed by SMART SPP project partner Global to Local.

The environmental benefits of EVs cannot be assessed on a generic basis. There is certainly no doubt about the fact that EVs can significantly contribute to reduce pollution and in urban environments. However, as the energy mix of each country plays an important role for the CO_2 emissions of the electric drive along its life-cycle, the abatement potential of EV technology has to be calculated and considered on a case-specific level.

More information on current projects using and testing electric vehicles can be found in Annex II.

5.2 Hybrid electric vehicles

In contrast to electric vehicles, in a hybrid electric vehicle (HEV) at least one of the energy stores, sources or converters delivers electric energy. In most cases the energy converters within a HEV consist of a battery pack, an electric machine and an internal combustion engine.

HEVs are further classified according to the size of their electric engine: Currently, HEVs still have less powerful electric engines and battery packs and are therefore called "Mild HEV". This

[12] Cf. Jantzen, M.; Aufbruch in ein neues Zeitalter. In: Photon – Das Solarstrom-Magazin, 9/2008, pp. 52-63

means that the electrical assist cannot operate alone, but works always together with the internal combustion engine. “Full HEV”, in comparison, have the ability to operate all electrically in some operation modes, generally at low average speed. At higher speeds and longer distances, however, also Full HEVs for efficiency reasons only use the mechanical drivetrain.

Moreover, HEVs are also distinguished regarding the configuration of the electric and combustion engine. This configuration can be parallel, which means that both the electric and the combustion engine can provide final propulsion power (“Parallel HEV”). In contrast to this, within a “Series HEV” only the electric engine can provide propulsion power.

The worldwide HEV fleet accounts for 1,040,000 units, whereas almost all of them (1,006,000) are located in the US. In Europe, so far only a few thousands HEV have been sold, especially in Sweden, Netherlands, Italy and Switzerland. Important manufacturers are Toyota, Honda, Lexus, Ford and Nissan. By the end of 2007, the cumulative sales figures of the Toyota Prius were already exceeding 500,000 units, followed by Honda Civic with approximately 150,000.[13]

Generally speaking, HEV are most advantageous in congested urban conditions with stop-and-do traffic characterised by a relatively low top speed and a limited required range[14].

5.3 Plug-in hybrid electric vehicles

As the possible next step in electrification of road transport plug-in hybrid electric vehicles (PHEV) are discussed. These vehicles are equipped with a battery pack providing a high storage capacity, with an ability to charge the battery by plugging in a vehicle cable. Due to the increased battery capacity and the possibility of braking energy recovery, the maximum all-electrical range and / or the maximum all-electrical speed of the vehicle can be increased. These performance criteria meet important consumer needs and enhance their acceptance towards the electric drive. Although a large variety of design options for PHEV are possible, all will use electricity from the grid to replace liquid fuels by internal combustion engines in vehicles.

A major advantage of PHEVs is that they are potentially even more efficient than HEVs. The reason for this is the limited use of the PHEVs internal combustion engine that may allow the

[13] Cf. International Energy Agency; Hybrid and electric vehicles, Annual report of the Executive Committee and Annex I over 2007, March 2008.

[14] Cf. International Energy Agency; Hybrid and electric vehicles, Annual report of the Executive Committee and Annex I over 2007, March 2008.

engine to be used as close as possible to its maximum efficiency. While e.g. a current Toyota Prius converts fuel to motive energy on average at about 30% efficiency (well below the engine´s 38% peak efficiency) the engine of a PHEV would be likely to operate far more often near its peak efficiency because the batteries can serve the modest power needs.[15]

The optimum battery size of a PHEV predominantly depends on the distance that the vehicle will be driven between charges. A recent US study[16] has shown that for urban driving conditions and frequent charges every 10 miles (16 km) or less, a PHEV with an all electric range of about 7 miles would be a robust choice for minimizing gasoline consumption, cost, and greenhouse gas emissions. However, it stressed that this result refers to US circumstances and does not necessarily has to be transferable to European conditions. Thus, a case-specific assessment of the actual requirements is indispensable before starting the procurement activity.

Although the plug-in hybrid technology has still to be developed and optimized, it is considered to be the most promising approach regarding energy savings and CO_2 abatement potential in the short term. PHEV are expected to be available on the market by 2010, e.g. Toyota announced to provide a PHEV version of the Prius by that time. Moreover, in the meantime most car manufacturers have started development efforts of models in this area.

Again, further information concerning existing and near-term available PHEVs can be found in the document “Electric Vehicles – a briefing paper” by Global to Local.

5.4 Battery technology

One of the greatest challenges for the marketability and optimisation of PHEVs in particular and electric / hybrid vehicles in general is the further development of the battery / storage technology. Currently, the baseline technology for almost all electric vehicles being built in large quantities and by major manufacturers are nickel metal hydride batteries (NiMH). Important producers for these cells are Panasonic, Sanyo and Cobasys.

In order to increase the energy density and efficiency of the storage system, lithium-ion (Li-Ion) batteries are being developed for the automotive sector. Thus, within the next generation of electric vehicles rechargeable Li-Ion batteries will play an important role. These cells are

15 Cf. http://www.nrel.gov/vehiclesandfuels/vsa/pdfs/40970.pdf

16 Cf. http://www.cmu.edu/me/ddl/publications/2009-EP-Shiau-Samaras-Hauffe-Michalek-PHEV-Weight-Charging.pdf

already best available technology for consumer electronics such as mobile phones and portable computers. However, the upscaling of these relatively small units to larger cells providing sufficient reliability and safety still requires considerable R&D efforts. Furthermore, also the battery management system has to be elaborated. Basically, Li-Ion batteries provide a number of advantages over NiMH (and other batteries), including[17]:

- Higher voltage (3.7 V for Li-Ion vs. 1.2 V for NiMH, resulting fewer cells for a given voltage);
- Lower weight (gravimetric energy density of approximately 125 Wh/kg for Li-Ion vs. 75 Wh/kg for NiMH, making them also especially suitable for lightweight applications, such as electric cycles and electric scooters);
- Smaller volume (gravimetric energy density of approximately 300 Wh/L for Li-Ion vs. 200 Wh/L for NiMH, making them also especially suitable for small sized applications);
- Longer service life (at least 500 deep discharge cycles for Li-Ion vs. below 300 cycles for NiMH);
- Better quick charge performance (below 1.5 hours for Li-Ion vs. 1.5 – 3 hours for NiMH);
- Lower self discharge rate (below 5% per moth for Li-Ion vs. 15-30% for NiMH);
- Higher thermal resistance (providing a wider range of service temperatures);
- Lower hazardous potential (no heavy metals like Nickel required).

Due to their lower specific weight and the higher efficiency, the energy demand of an HEV powered by lithium-ion technology is expected to decrease by approximately 25%[18].

The costs for Li-Ion batteries depend on the required range of the electric operation mode. For a Prius, Toyota quoted a price of $ 5,000 for every 10 miles (16 kilometres) of all-electric range provided.[19]

Against the background of the rapidly increasing R&D engagement of major car manufacturers (such as Daimler, General Motors and Toyota) in Li-Ion technology, questions have been

[17] Cf. http://www.compactpower.com/lithium.shtml
[18] In comparison to NiMH cells, cf. Degussa ServiceNewsletter 14/2006
[19] Cf. http://www.advancedautobat.com/market/Toyota_seeks_battery-price.html

raised about the long-term supply availability of Lithium to support the mass production of Li-Ion batteries. Following an exploratory analysis, a reasonable consumption factor for lithium-ion batteries is 0.14 kg of Lithium per 1 kWh of electrical capacity. Based on current assessments of global Lithium supply of approximately seven billion kg, this analysis implies that available Lithium can support a production of approximately 33 billion strong / full HEVs. It has to be taken into account that the global annual production of all vehicles is currently at approximately 70 million and the total population of vehicles on the road today is approximately 800 million.[20]

Both Li-Ion and NiMH batteries can be recycled. Toyota, for instance, has already established a recycling programme in the US under which dealers are paid $ 200 credit for each end-of-life battery returned[21]. Besides recycling, also a secondary market for further use of PHEV batteries is about to be established: General Motors has been asked by utilities interested in using worn out Volt[22] batteries as a power storage system[23].

Furthermore, the awareness of battery safety regarding Li-Ion has increased over the past years as a result of the massive recall of portable Li-Ion batteries in notebook computers and cell phone applications. As a typical HEV Li-Ion battery will include a string of 50 to 100 serially connected individual cells operating at between 150 and 300V and in harsher thermal and mechanical environments than computer batteries, hybrid-vehicle manufacturers and their battery suppliers are understandably cautious. However, technological improvement has been made by introducing a ceramic membrane between the two electrodes instead of the currently used polymer membrane[24]. Yet the questions of product safety and reliability cannot be answered thoroughly until field introduction occurs.[25]

5.5 Charging infrastructure

Besides battery technology, also appropriate charging infrastructure plays an important role for the rollout of electric vehicles as well as their environmental performance.

20 Cf. http://www.compactpower.com/faq.shtml
21 Cf. http://www.toyota.com/about/our_commitment/environment/
22 The Volt is a PHEV manufactured by General Motors.
23 Cf. http://tech.blorge.com/Structure:%20/2008/06/16/toyota-laughs-while-chevy-volt-battery-power-is-ripped-in-half/
24 Cf. http://www.creavis.com/site_separion/en/default.cfm.
25 Cf. http://www.autofocusasia.com/production_manufacturing/lion_batteries_hybrid.htm.

In France, for example, Électricité de France (EDF) and Toyota have installed numerous recharging points for PHEVs on roads, streets and parking lots[26]. EDF is also partnering in UK with Brighton-based Elektromotive Ltd. The company started developing charging station technology in 2003 and installed its first charging post called 'Elekrobay' in the centre of London in 2006. To date, it has installed approximately 80 charging bays in London and a further 40 in cities and shopping centres around the UK. Elektrobay provides recharging facilities for pure electric and plug-in hybrid electric cars. The eye-catching charging stations are located at the roadside and in multi-storey car parks. They are programmed to allow full data transfer between the power supplier and the consumer by using the latest Power Line Communication (PLC) technology (developed by EDF). This PLC integration allows the Elektrobay to 'talk' with a recharging vehicle by sending and receiving digital signals via the power cable without the need for additional wires. The resulting 'conversation' can exchange data and discuss billing, power requirement identification, transaction security and safety.[27]

As already mentioned before, the CO_2 abatement potential of EVs and PHEVs is highly dependent on the type of the electricity mix and its proportion of fossil fuels. An US study[28] predicts that in areas where more than 80% of electricity derives from coal-burning power plants, local net CO_2 emissions will increase, while for PHEVs recharged in areas where the grid is fed by power sources with lower CO_2 emissions, net CO_2 emissions associated with PHEVs will decrease correspondingly. Thus, the environmental performance of EV and PHEV procurement can be increased significantly if the charging infrastructure is closely connected to use of renewable energy sources (RES). This can be achieved by the simultaneous procurement of green electricity or – even better – by integrating RES infrastructure into charging infrastructure, e.g. by installing photovoltaic panels directly at the charging stations.

Moreover, EVs and PHEVs can contribute to the load management of the electric grid and a more efficient use of existing electric production capacity. This implies that these vehicles are charged primarily during off peak periods (i.e. at night), or equipped with devices to interrupt charging during periods of high demand. By using a special vehicle to grid technology, excess battery capacity can be transferred back into the grid and then recharge during off peak times using cheaper power. With this option, the term "Cash-Back Hybrids" was coined for PHEVs in order to describe payments to car owners for putting their batteries on the power grid. In order to foster the use of electric vehicles in general, batteries could also be offered in low-cost

26 Cf. http://presse.edf.com/accueil-com-fr/presse/communiques-de-presse/noeud-communiques-et-dossier-de-presse/communiques-2007/edf-et-toyota-annoncent-un-partenariat-technologique-en-europe-relatif-aux-vehicules-hybrides-rechargeables-105819.html.

27 Cf. http://www.elektromotive.co.uk/html/news.php

28 Cf. http://www.aceee.org/store/proddetail.cfm?CFID=1941952&CFTOKEN=35186425&ItemID=418&CategoryID=7.

leasing or renting or by donation (including free maintenance) by the public bodies, in a vehicle-to-grid agreement. [29].

Another interesting corporate approach in the field of charging infrastructure can be found at 'Better Place', a new US-based company with the following business concept[30]:

- The customer purchases an electric vehicle (without battery) of any manufacturer (currently only cars from Renault-Nissan are possible);
- Both battery and electricity (strictly based on renewable energy resources like solar power and wind) are provided by Better Place, whereas only the effective mileage has to be paid;
- The batteries to be owned by Better Place are planned to have a maximum range of 160 km and can be recharged at the workplace or at public parking areas;
- In order to enable longer distances, battery changing stations will be established where exhausted batteries are exchanged fully automatic by fresh ones.

Besides the US, Better Place plans to establish charging infrastructure also in European countries (e.g. Denmark and Portugal)[31].

Even greater than the further development of battery technology and charging infrastructure, however, will be the challenge to change consumer behaviour to some extend. This aspect is considered to be one of the most important success factors for the sustainable implementation of PHEVs, HEVs and EVs. It has to be kept in mind that the energy-saving and CO_2 abatement potential of these innovative technologies can only be thoroughly realised, if they are applied in smaller and lighter vehicles.

29 Cf. http://carbonnation.info/2009/02/04/ferc-boss-dubs-the-plug-in-a-cashback-hybrid/
30 Cf. www.betterplace.com
31 Cf. Vieser, S.; Anschluss gesucht. In: Technology Review spezial – Auto der Zukunft, 1/2009, pp. 116-117.

6 In-depth characterisation of innovative RES heating / RES cooling systems

6.1 RES heating

Heating of public buildings is mainly responsible for building-related CO_2 emissions. This has been confirmed through a study carried out by the German Energy Agency (dena) with approximately 850 civilian government buildings: It resulted that in 2005 approximately 58% of CO_2 emissions were generated through heating[32]. The remaining 42% of CO_2 emissions in 2005 were generated through the use of electric energy.

Before considering substitution of conventional heating energy for the buildings with heating energy from renewable sources it should first be checked fundamentally whether overall savings of heating energy can be realised. Regularly, 50% heating energy can be saved through insulation of facades and replacement of windows. Further 20 to 30% heating energy can be saved through an adapted automatic control technology which controls rooms according to defined needs and foresees a temperature reduction at night, on weekends and during holidays. Most appropriately, only the remaining heating energy demand should be covered by renewable energies.

Renewable energy sources (RES) offer the opportunity to provide nearly CO_2-free heating energy. With regard to solar energy, energy demand is limited to the amount of energy needed for module production as well as to electric energy for operation of control and pumps. In the case of renewable primary products it can be assumed mathematically that the plants will emit just as much CO_2 as they have absorbed during growth. CO_2 emissions from renewable primary products are mainly generated through cultivation (fertilisers, fuel for agricultural machinery) and from processing and transport of raw materials). However, it should individually be checked for renewable energy sources also whether the chosen system really leads to noticeable CO_2 reductions compared to a conventional system.

32 Lisa Buchner, Jens Gröger, Deutsche Energie-Agentur GmbH (dena); Monitoring der Selbstverpflichtung der Bundesregierung zur CO2-Minderung; http://www.iemb.de/veranstaltungen/dokumentationen/bet2007/bet-2007_groeger_dena.pdf

The most important sources for renewable energies respectively for related heating technologies are:

- Solar heat;
- Geothermal energy / heat pumps;
- Biomass boilers and
- Biogas co-generation plant.

6.1.1 Solar heat

Solar assisted heating systems have already successfully been in use in residential buildings for years. Normally, they are used for the generation of hot process water, only rarely with a view to support room heating. In summer, buildings using solar assisted heating systems can rely only on hot process water generated with solar heat thus allowing complete switch off of the central heating system.

The operating mode of solar assisted heating systems consists in heating up a liquid carrier medium in solar collectors aligned to the sun, further transfusing the generated heat through a heat exchanger into the process water. With the use of a sufficiently dimensioned and well insulated hot water storage tank the heat can be made available constantly over the day. The solar assisted heating system is able to annually save up to 50 litres fuel oil respectively 500 m^3 natural gas or 400 kWh heating energy per square meter of collector area. In addition to drinking water treatment it is possible to use the solar heating system as heating support during inter season period and in winter. The integration of such a solar heating support is done via increasing the return temperature in a buffer or combination storage tank.

In Europe, a large number of producers and qualified planning agencies for solar heating systems exist.

Average investment costs for solar heating systems range between 500 and 1,000 Euros per m^2 of net collector area.

The annual CO_2 saving potential can be quantified with approximately 140 kg CO_2 per m^2 of net collector area.

6.1.2 Geothermal energy / heat pumps

Heat pumps draw ambient heat at a relatively low temperature level (e.g. 10° C), use it for heating up a carrier medium and thus increases its temperature up to a level suitable for heating (e.g. 40° C). Temperature lifting is done via compression, i.e. via adding mechanical energy. For example, heat pumps can use heat from ambient air, from geothermal or ground water energy. Currently, heat pumps are mostly powered by electricity which deteriorates the CO_2 balance of this technology. In that respect, a promising alternative is powering heat pumps with gas engines or with gas powered absorption pumps which could however not yet penetrate the market.

The higher the temperature difference between the utilised heat source and the interior room has to be, the more electric energy is needed to raise the temperature level. Hence, heat pumps are more sensible to operate with heating systems which require only a low heating temperature (such as floor and surface heating). The ratio between used thermal energy and used electric energy needs be as high as possible. In case this ratio, the so-called Coefficient of Performance (COP) is smaller than 3, the heat pump does not lead to CO_2 savings compared to a condensing boiler run with natural gas.

Water / water respectively brine / water heat pumps use ground water or geothermal energy as heat source. In this case, a constant temperature level of the heat source over the year is advantageous.

Geothermal energy can as much be used as support in bivalent systems as also as unique heat source. The heat stored in the earth can either be transfused to the heating circle through heat collectors that are passed close to the surface or through geothermal sensors going further down into the earth.

Heat pump technology has already been available on the market for some years but is however mostly restricted to residential applications.

Average investment costs for heat pumps lie between 250 and 500 Euros per kW_{th}. The annual CO_2 saving potential is between 115 and 250 kg per kW_{th}.

6.1.3 Biomass boiler installations

Biomass boiler installations are run on solid fuel (wood, halms), on gaseous fuel (biogas, sewage gas, landfill gas) or on liquid fuel (palm oil, biodiesel, bio alcohol).

In most areas of use the fuel is wood in the form of woodchips. Their upstream production processes are little energy intensive thus giving wood a beneficial CO_2 balance.

However, the precondition is that wood is available in sufficient quantities and does not need to be transported over long distances, e.g. as scrap wood from regional forestry and from wood treatment facilities.

Usually, the heat load of single or several public administration buildings is around 1 to 5 MW and thus suitable for fully automated combustors. One problem related to running wood based heating installations is the emission of particulate matter (PM) that has to be reduced through efficient PM separation.

Biomass boiler installations should be designed on the basis of the heat demand for a certain base load of a building, which is to be supplied in order to allow continuous full load operation. Therefore, usually additional peak boilers (e.g. gas boilers) are installed in order to cover the peak loads.

The technology of biomass boiler installations is widely advanced and there are numerous producers of such installations in Europe. Should the prerequisites for the long-term delivery of the renewable primary energy be given, biomass boiler installations could be run with more profit than comparable boiler installations that run on fossil fuels.

Average investment costs of biomass boiler installations are in the between 270 up to 370 Euros per kW_{th}. The annual CO_2 saving potential lies around 570 kg CO_2 per kW_{th} installed capacity.

6.1.4 Biogas co-generation

Biogas which is for example generated from fermentation of agricultural residues can directly be utilised for running combined heat and power plants without high cleaning efforts. The basic principle of co-generation is that the utilised primary energy is transformed into approximately

30% electricity and 60% thermal energy. This means a considerable efficiency advantage compared to conventional electricity generation in condensation power plants.

The economic benefit of a combined heat and power plant depends largely on its operating time and thus on its electricity and heat consumption. Usual operating times lie around 6.000 operating hours per year. Whereas in case of over production, electricity can be fed into the public grid and is thus remunerated, excessive heat, e.g. in summer, can rarely be used profitably. Combined heat and power plants are thus especially environmentally and economically interesting if there is a relevant heat demand in summer, e.g. if there is high hot water demand. In public buildings co-generation is well suited for e.g. hospitals, prisons, swimming pools and schools with gymnasiums. In large fully air-conditioned administration buildings combined heat and power plants can be combined with absorption cooling installations (cf. section on RES cooling). In that case waste heat of co-generation is used for the production of cooling energy in the absorption process.

The use of biogas co-generation is particularly interesting from a profitability point of view in countries where electricity from renewable sources is particularly remunerated when fed into the public grid (e.g. in Germany, Portugal and Spain).

Combined heat and power plants are meanwhile widely spread and available on the market in good quality. The optimal design and planning of such installations should however be left to specialised consulting engineers.

Average investment costs for combined heat and power plants depend on the connected load and on average lie between 650 and 1,700 Euros per kW_{el}. The annual CO_2 saving potential amounts to around 6.000 kg per kW_{el} for biogas co-generation compared to the conventional separate supply of electricity and heat. The annual expenses for service and maintenance of the installations lie around 8 to 12 % of the investment costs.

6.2 RES cooling

The market for air conditioning of buildings is growing steadily. In that respect, an EU study forecasts an increase of the air conditioned building surface by a factor 5 for the period 1990 to 2020.

This is caused by grown comfort requirements and increasing climate extremes, which more frequently lead to default equipment of buildings with air conditioning.

In order not to accompany this trend with considerable progression of CO_2 emissions (thus indirectly further augmenting the cooling need), supply of cooling performance should in future be covered by renewable energies.

The use of solar energy for air conditioning is particularly attractive due to the following reasons:

- Simultaneity of solar gains and cooling loads;
- Operation time extension of solar assisted heating systems (heating in winter, cooling in summer) and
- Reduction of electric peak load in summer (when power plant facilities have to reduce their capacity due to higher temperatures).

The technology of solar assisted air conditioning is not yet fully mature and thus needs additional investors such as public authorities which would like to directly promote research and development. At the moment, there are about 60 installations for solar cooling in Europe with a total cooling performance of about 6 MW[33] (in 2006).

However, also for air conditioning with renewable energies it is a matter of principle to firstly avoid unnecessary cooling loads in buildings and to use the possibilities for free cooling, such as:

- Shading of sunny side windows;
- Renouncement of large surface glass facades;
- Removal of server rooms from office areas;
- Use of energy saving as well as low waste heat office equipment and lighting;
- Cold recovery from exhaust air as well as
- Use of free cooling through window ventilation or mechanical ventilation in cooler night hours.

33 Cf. Jan Albers (IEMB); Solarthermische Kälteerzeugung - Techniken, Systeme, Erfahrungen; Vortrag auf den Berliner Energietagen 2006; http://www.iemb.de/veranstaltungen/dokumentationen/bet2006/albers_2006.pdf

There are a large number of technological possibilities to make solar energy useful for cooling purposes. The project SOLAIR[34] financed in the framework of the Intelligent Energy Europe Programme gives a good overview on currently available technology for solar assisted air conditioning processes, including best practice examples and planning tools. In the following the most important processes are described.

6.2.1 Dessicant rotors / adsorption chillers

In open air conditioning processes the refrigerant (water) is in direct contact with the atmosphere. Water is added to the aspired ambient air in order to lower its temperature through the use of evaporative cooling. This process is also called „Desiccant and Evaporative Cooling – DEC“. Since very humid air would arise from evaporative cooling, it needs to be dehumidified first. For that purpose, a dessicant rotor is used. The core element of this unit consists of a rotating solid adsorption material, usually silica gel or lithium-chloride (LiCl) which is in direct contact with supply and exhaust air streams. Supply air encounters a dry adsorption material and is dehumidified. Exhaust air is heated up to typically 60 to 95° C before entering the dessicant rotor and thus regenerates the adsorption material. In case of solar assisted air conditioning, this temperature increase of exhaust air takes place with heat from solar collectors. The comparatively low temperature level for the regeneration of the dessicant rotor can be provided by commercially available flat plat collectors.

The efficiency of open air conditioning processes is defined through the Coefficient of Performance (COP) which illustrates the ratio between cooling performance and necessary driving heat performance.

Typical parameters for cooling installations with dessicant rotors are[35]

- Driving temperature of 60 to 95° C;
- Coefficient of Performance of 0.4 to 0.7;
- Large range of cooling performance from 50 to 500 kW.

[34] Cf. SOLAIR – Increasing the Market Implementation of Solar Air Conditioning Systems for Small and Medium Applications in Residential and Commercial Buildings; http://www.solair-project.eu

[35] Cf. BINE Informationsdienst; themeninfo I/2004; Klimatisieren mit Sonne und Wärme; Bonn 2004; http://www.bine.info/fileadmin/content/Publikationen/Themen-Infos/I_2004/themen0104internet-x.pdf

Currently, only a few Asian and European manufacturers produce adsorption chillers. The two historical players are Japanese, but also a German manufacturer has entered the market:

- Mayekawa, Japan;
- Nishiyodo, Japan;
- SorTech, Germany.

6.2.2 Absorption chillers

Absorption chillers are used as cooling technology since years and thus are much more common than adsorption chillers. Normally they are run on district heat, industrial waste heat and waste heat from co-generation. Nevertheless, solar thermal energy is also a possible heat source since suitable sorption materials for its high temperature level (60 to 120° C) are available. The installations run with a liquid solution consisting of a refrigerant / sorption pair which is usually water and lithium-bromide (LiBr) or ammonia (NH_3) and water. Systems with a H_2O / LiBr solution are used for applications above approximately 4°C and are suited for building air conditioning. Systems with NH_3 / H_2O solutions can reach temperatures clearly below 0°C and can thus be used as refrigeration installation.

Instead of directly compressing and vaporising a refrigerant – as done in conventional compression chillers – the refrigerant in the absorption chiller is collected by a liquid sorption material and expelled again in a separate process step through the addition of heat. With condensation and subsequent expansion of the refrigerant, a temperature level of e.g. 16° C can be reached allowing cooling down warm supply air through a heat exchanger and can thus be used for cooling rooms.

There are many pilot projects with solar-driven absorption chillers and the technology is largely mature. The evaluation of the pilot projects within a range of 10 to 700 kW cooling performance resulted in a necessity for 3 to 4 m^2 solar collector area per kW cooling performance in average. Coefficients of Performance from 0.4 to 0.8 are reached with single-level absorption chillers. Double-level absorption chillers reach COP values up to 1.3. The specific costs amount to 4,000 € per kW cooling performance in average.

The European manufacturers of absorption chillers are located in Austria, Italy, Germany, Portugal, Spain and Sweden, but also outside Europe producers exist; examples are:

- EAW, Germany;
- Rotartica, Spain;
- Yazaki, Japan;

System providers of small scale cooling systems (below 30 kW, both adsorption and absorption chiller technology) are e.g.:

- Phönix SonnenWärme, Germany;
- Solarnext, Germany;
- Solution Solartechnik, Austria;

According to first assessments, the annual CO_2 saving potential lies around 150 kg per kW of cooling power[36]. For European conditions, the specific costs for solar cooling kits[37] currently amount to approximately 4,500 EUR / kW, expected to decrease to 3,000 EUR / kW in the near future[38].

6.2.3 Steam jet ejector chillers

The core element of steam jet ejector chillers is the steam jet compressor, which increases the refrigerant steam up to the pressure level of the refrigerant condenser through a thermo-mechanical process. Water is used as refrigerant. Whereas the pressure increase in conventional compression chillers is done by an electrically powered compressor, it is done here with a steam jet compressor powered by pressurised steam at a high temperature and pressure level (200° C, 13 bar overpressure).

In the case of solar assisted air conditioning, the pressurised steam comes from a concentrated collector array (e.g. parabolic trough collector). The disadvantage of these systems is that they only run with direct sunlight and that the collector array is relatively complex. The technology is especially to be considered for countries with high direct radiation

36 Cf. http://www.solair-project.eu/177.0.html

37 The specific costs comprise solar thermal collectos, hot water storage, pump-set, chiller, re-cooler, partly cold water storage and system controller, but exclude distribution and installation costs.

38 Cf. http://www.solarnext.eu/pdf/ger/publications_presentations/jakob/08SolarPartnerSued_Solare_Kuehlung.pdf

such as the Mediterranean region. The good dynamic behaviour of the systems, providing higher cooling performance at a high driving heat capacity is an advantage. The steam jet ejector chiller is very efficient and the corresponding Coefficient of Performance can be set at higher than 1. In case the solar generated pressured steam cannot be collected fully by the chiller, systems with a steam turbine are conceivable which produce electric energy as a byproduct.

Until now, only a few pilot projects for solar assisted air conditioning with steam jet ejection chillers exist[39]. However, the actual cooling technology including the steam jet compressor has been proven and tested for many years and is used regularly in the chemical industry. The combination of this technology with concentrated solar collectors currently has little market relevance and should therefore be supported specifically.

The development of solar assisted air conditioning systems in general is not at all yet concluded. Considerable improvement potentials lie just as much in the interaction of components as in the system technology itself. Currently, solar assisted air conditioning systems are further standardised through producers and are optimised for smaller areas of performance such as the air conditioning of residential buildings; the goal being to reduce the still very high specific costs for these systems. Through carrying out publicly funded projects on solar assisted air conditioning this technology can be developed further and made accessible to a broader market.

39 Cf. http://www.fabrikderzukunft.at/results.html/id5031

7 Characterisation of innovative ICT solutions

Within the field of ICT equipment this report is focussed on solid state computers as this technology is discussed as a promising approach for further energy savings in the computer sector. Moreover, ESPO as one of the public purchasing authority of the SMART SPP project expressed its interest to influence procurement in this sector via bundling demand.

The data storage of solid state computers consists of a solid-state drive (SSD) that uses solid-state memory to store persistent data. Unlike flash-based memory cards and USB flash drives, an SSD emulates a hard disk drive interface, thus easily replacing it in most applications. Compared to hard disk drives, SSD devices offer a series of advantages (cf. table 6).

Table 6: Advantages and disadvantages of SSD technology

Advantages of SSD technology	Disadvantages of SSD technology
Short access times	(still) rather low capacity
Shock resistance	(still) rather high prices
Compact size	Limited number of write accesses / limited Service life
Silent operation	Large differences in quality
Energy savings potential	

For example, the data access is much faster: Whereas a hard disk drive needs five to ten milliseconds for write / read access, SSD technology only 0.1 to 0.2 milliseconds are required. With no moving parts, the technology also offers more than four times greater shock resistance than traditional hard disk drives, which rotate with several thousand revolutions per minute and operate with movable read and write heads. Furthermore, due to their compact size, SSD can for instance contribute to thin and light notebook design. SSD are available at a size of 1.8, 2.5 and 3.5 inches and also first 1.0 inch devices are already available on the market. Moreover, another major advantage of SSD technology is their completely silent operation. Regarding energy demand, a SSD drive consumes approximately 1 Watt in the access mode. In contrast to this, hard disk drives at a size of 2.5 inches use 2.0 – 2.5 Watts with 3.5 inch devices exceeding a consumption of 10 Watts in some cases. Numerically, this implies an energy savings potential of up to 60% for 2.5 inch devices and 90% for 3.5 inch devices. When referring the absolute savings to the total energy consumption e.g. of a notebook computer (30-50 Watts), the relative savings do not exceed 30%. Furthermore, it has to be taken into account that the energy demand heavily depends on the quality of the SSD unit.

One of the disadvantages of SSD technology is the relatively low capacity of the devices. Currently, capacities of 8, 16, 32, 64, 128 and 256 GB are available. However, in April 2009 a 1 TB SSD was introduced by OCZ. Even if for most office applications SSD solutions are already existing, their price is still significantly higher than hard disk drives. For example, regarding notebook computers the extra charge accounts for 200 – 400 Euros per unit, reaching up to 1000 Euros in some cases. A decline in prices by 50-70% p.a., however, can be recorded and thus price parity with hard disk drives is expected within 3 – 4 years. Another drawback is the limited number of write accesses. Whereas unlimited erasing and re-writing is possible for hard disc drives, in flash-based memory devices the number of cycles is limited between 100,000 and several million depending on the quality of the memory and the integrated controller. Another important parameter for the durability is the memory type: Single level cell (SLC) memories are more durable than multi level cell memories (MLC), but also more expensive. As a consequence, SSD devices of low quality provide a service life of only 3-5 years.

Examples for manufacturers of notebook computers with SSD technology are Apple (McBook Air), Dell (Latitude E4300), Lenovo (Thinkpad X301), LG (P510) and others. Usually, customers of these products have the choice between conventional hard disk drives and SSD drives for extra charge (as mentioned above).

Besides notebooks, solid state drives are also a highly innovative alternative for server and storage systems, which are currently entering the market. For example, Texas Memory Systems has recently developed the RamSan-620 storage system with a capacity of 5 TB. In order to take best advantage of the fast access rates of SDD technology, this device is intended to be used especially for processing of online transactions, data warehousing and video editing.

8 Conclusions and recommendations

According to the analysed demand of the participating public authorities, LED lighting was assessed as the most promising emerging technologies for the SMART.SPP project.

Furthermore, also electric / hybrid vehicles, RES heating / cooling and solid state computers were identified as interesting innovative technologies with a considerable environmental abatement potential.

Thus, within this report all the above mentioned technologies were investigated and assessed against the objectives of this project. This analysis comes to the following major findings and recommendations:

- Regarding innovative lighting solutions, street and /or office lighting are especially suitable for a pre-commercial approach within the SMART SPP project; these applications of the LED technology provide a great energy saving potential (e.g. street lighting more than 30%) and are about to enter the mass market within the next 2-3 years.

- Same is applicable for plug-in hybrid vehicles, which use an innovative storage technology (such as lithium ion batteries); moreover, the combination with innovative charging infrastructure powered by renewable energy resources should be taken into account.

- Concerning heating and cooling with renewable energy sources especially cooling systems using adsorption, absorption and steam jet ejector chillers are recommended for pre-procurement activities; however, also well established RES heating technologies (especially solar heat, geothermal energy / heat pumps, biomass boilers and biogas co-generation plants) should be taken into account if the procurement activities of the SMART SPP project catalyse the market entry in countries where these technologies are not yet existing.

- Last but not least, also computers with solid state drives should be considered for pre-procurement activities, not only due to their energy savings potential, but also their technological advantages.

9 References

9.1 Manufacturers' information on "traffic lighting" (March 2009)

- **Royer Signaltechnik GmbH**; Pattensen, Germany (www.royersignal.de)
- **Preiser Technik OHG**; Bruchköbel, Germany (www.preiser-technik.de)

9.2 Manufacturers' information on "street lighting" (March 2009)

- **AUTEV AG**; Brandenburg, Germany (www.autev.de)
- **h.e.l.-Lichttechnik GbR**; Vechta, Germany (www.hel-licht.de)
- **Joliet Technology SL**; Figueres, Spain (www.joliet-europe.com)
- **LANZ Manufaktur**; Simmertal, Germany (www.raledlamp.de)
- **LED Worx GmbH**; Wien, Austria (www.ledworx.com)
- **LightFactory.eu**; Fehmarn, Germany (www.lightfactory.eu)
- **BEGA Gantenbrink-Leuchten KG**; Menden, Germany (www.bega.de)
- **2K Moxa Lighting GmbH**; Moxa, Germany (www.2k-leuchten.de)
- **INDAL Deutschland GmbH**; Berlin, Germany (www.indal-gmbh.de)
- **Philips GmbH**; Springe, Germany (www.philips.de/lighting)

9.3 Websites for LED technology in office lighting

- **Overview on manufacturers** (www.led-info.de) **and** (http://www.topten.ch/uploads/images/download-files/LED-Test_Messbericht_130109.pdf)

- **US Energy Department** (http://www1.eere.energy.gov/buildings/ssl/benchmark.html)

9.4 Project and Research Instituts' Websites

- **LED City** (http://www.ledcity.org/)
- **TU-Darmstadt, Germany** (http://www.emk.tu-darmstadt.de/institut/fachgebiete/lt/forschung/arbeitsgebiete/)
- **Lighting Reasearch Institute NY, USA** (http://www.lrc.rpi.edu/)
- **Taiwan Industrial Technology Research Institute (ITRI)** (http://www.itri.org.tw/eng/Research/Focus-Area/focus-sub-area-category.asp?RootNodeId=0301&NodeId=03012&FieldCD=02500)
- **OLED100.EU** (http://www.oled100.eu/homepage.asp)

10 Annex 1

In order to asses the needs of the participating procurement authorities a document was provided that included a matrix that the public authorities should fill in. Within this matrix, the following aspects were requested:

- Application: concrete application within the public authority's purchasing portfolio the technology would be suitable including a new application for an already existing technology but that has not been used in such application;
- Political commitment: positive commitment of the political decision-makers in the public authority's municipality regarding the technology (high / medium / low);
- Related contract: reference to an already existing contract purchasing other technologies for the same use;
- Type of contract: preferred procurement contract distinguishing into purchase, leasing and service;
- Third party involvement: cooperation with other companies or organisations, if the technology is not going to be handled by the public authority's own staff;
- Contract volume: quantification of the number of units the public authority would be able to procure of the mentioned application;
- Contract renewal time: point of time (month and year) when existing contracts for the mentioned applications will be renewed (where appropriate);
- Procuring department: department(s) which is (are) in charge of developing the tender and contracting the selected technologies;
- Energy savings expectations: estimated energy savings potential of the technology on a qualitative basis (high /medium /low);
- Cost savings expectations: estimated cost savings potential or expectations of the technology on a qualitative basis (high /medium /low);

- Risk potential: denomination of possible risks which the public authority would encounter especially linked to buying the innovative application (e.g. dealing with the possible failure of the project and / or the financial risk).

The SMART SPP public authorities were not obliged to give detailed feedback according to the above mentioned aspects for all emerging technologies under consideration, but only for those, which they had already some interest in. At the end of the document, the procurement authorities were asked to indicate which technologies they would like to select for the pre-procurement process and why.

While gathering the contributions on the document explained above the Öko-Institut encountered some difficulties. Especially information regarding the contract volume and the contract renewal time were missing in most cases, although these aspects are of major importance when evaluating the different emerging technologies. These findings reflect the fact that pre-procurement is a rather new and challenging approach for procurement authorities.

11 Annex 2

A selection of current Electric Vehicle (EV) projects in Europe

Country/City	Partners	Name of Project	Project Description	Time Frame	Technology used	Number of EVs used
Germany: Berlin[40]	Daimler, RWE	e-mobility Berlin	Daimler provides the EVs; RWE will build up an infrastructure of charging stations	To start: end of 2009	Lithium-Ion Batteries,; Electricity from regular grid	100 (Smart, Mercedes Benz)
Germany: Munich[41], (a second pilot project to start in Berlin in summer 2009)	BMW, E.ON	n.s.	The project aims at gaining practical experience with EVs, private consumers will not be able to participate	To start: May 2009	Lithium-Ion Cells; E.ON wants to provide electricity from Bavarian water works	At least 15 Mini-E cars (BMW)
Germany: Wolfhagen[42]	n.s.	n.s	The car was tested by six different users - among them the city administration and local businesses	4 weeks from March 2009	Nickel-Cadmium Battery; Electricity n.s.	1 Citroen Berlingo
Federal Ministry of Transport Building and Urban Affairs[43]	n.s.	Promo-tional Program-me: “Model Regions of electro mobility”	With the objective of making Germany a market leader in electro mobility, the Federal government will provide 500 mio Euros between 2009-2011, Regions in Germany are asked to apply	Applica-tion dead-line was April 22; the first project is to be funded by mid-2009	n.s.	n.s.

40 http://www.heise.de/autos/E-Mobility-Berlin-Elektroauto-Pilotprojekt-gestartet--/artikel/s/6409/0

41 http://www.heise.de/newsticker/BMW-testet-Elektroautos-in-zwei-deutschen-Grossstaedten--/meldung/133709

42 http://www.wolfhagen.de/de/aktuelles/meldungen/2008_05_05_45396976_elektroauto_rathaus.php?navanchor=

43 http://www.bmvbs.de/txt/de/artikel-,302.1068661/Foerderprogramm-Modellregionen.htm

Country/City	Partners	Name of Project	Project Description	Time Frame	Technology used	Number of EVs used
Denmark[44]	DONG Energy, Better Place, Automotive Energy Supply Corp, Renault	n.s.	To build up a national infractstructure for EVs	Agree-ment with Better Place in March 2008	Lithium-Ion Batteries developed by Automotive Energy Supply Corp; Windenergy	Renault EVs
Denmark: Bornholm	EDISON research consor-tium	EDISON-Project	The first step is to develop smart technologies to be implemented on the Danish island of Bornholm, designed to function as a testbed. This will allow researchers to study how the energy system functions as the number of EVs increases	25.02.09 - 2012	Cars: Batteries Windenergy; in 2011 the first cars should be available in Denmark	
Italy: Pisa, Rome, Milano[45]	Daimler, Enel	e-mobility Italy	Enel will install more than 400 charging stations, while Daimler will supply and maintain the EVs	To start: 2010	Lithium-Ion Batteries	More than 100 EVs (Smart ForTwo ED and Mercedes Benz (n.s.)
UK: London[46]	Daimler	n.s.	The cars were offered to selected clients, drivers do not have to pay the city congestion charges or motor vehicle taxes	Since 2007, in April 2009 London Mayor Boris Johnson pledged to increase EVs to 100 000	Lithium-Ion Batteries	100 Smart ForTwo

44 http://baseportal.de/cgibin /baseportal.pl?htx=/elwebt/main&localparams=1&db=main&cmd=list&range=0,9&cmd=all&Id=1740; http://www.greencar.com/articles/innovative-mass-marketing-renault-electric-cars.php

45 http://www.daimler.com/dccom/0-5-658451-49-1159926-1-0-0-0-0-0-9293-7165-0-0-0-0-0-0-0.html; http://www.autobloggreen.com/2008/12/15/e-mobility-italy-electric-drive-smarts-get-a-taste-for-pasta/

46 http://www.daimler.com/dccom/0-5-658451-49-1159926-1-0-0-0-0-0-9293-7165-0-0-0-0-0-0-0.html, http://www.smart.com/-snm-0135207752-1239438359-0000006282-0000001352-1239958337-enm-view/london/mpc-de_de_DE_EUR_urn:uuid:8439cbb4-e366-5fb1-8c8a-0226a7384cb2

Country/City	Partners	Name of Project	Project Description	Time Frame	Technology used	Number of EVs used
France: Paris[47]		Autolib'	Automobiles-en-Libre service would allow subscribers to pick up cars from dozens of collection points at any time of day without booking and leave them anywhere in the city. The electric cars would cost just a few euros a day to hire (project may be put on hold because of financial problems)	2010	In discussion: Cleanova: Lithium- Ion Battery BlueCar: Lithium-Metal-Polymer Batteries	4000 EVs
Netherlands[48]	ElmoNet, Th!nk	n.s.	The memorandum of understanding calls for Think to deliver the EVs in 2009, the Dutch government supports this early introduction with 10 mio. Euros	To start: March 2009	Sodium or Lithium Batteries	500 EVs
Austria: Vorarlberg[49]	Various[50]	VLOTTE	Drivers use a "mobilty card" for about 500 Euros/month which includes the maintenance of the car, free charging ; at the same time an infrastructure for charging stations is developed	2009-2010, afterwards the leasing of EVs to be extended	Different technologies and EVs are tested, renewable energy sources are used	100 EVs

47 http://www.businessgreen.com/business-green/news/2219706/paris-extend-electric-hire-car
48 http://www.think.no/think/Press-Pictures/Press-releases/Think-enters-the-Dutch-market-with-a500-unit-MOU
49 http://www.vkw.at/inhalt/at/vlotte.htm
50 http://www.vkw.at/inhalt/at/1214.htm