GREEN HIGHWAY DESIGN

FINAL REPORT IN FUTURE HIGHWAY DESIGN

GROUP 1 -

ARNAR AGUSTSSON, FREDRIK LINDGREN, LAISUO SU,

SHUANG CHEN, YANG BOWEN, YUNYU WANG, ZENG QIRAN

2013-12-13

CONTENTS

1 Introduction 2

2 Background 3

2.1 Vehicles 4

2.1.1 Why electrical vehicles? 4

2.1.2 Why personal transporters? 5

2.2 Road materials 5

2.2.1 Why solar roads? 5

2.2.2 Why noise-electricity generation? 5

2.2.3 Why bio-materials? 6

3 Design in-depth 6

3.1 Personal transporter: concept design 6

3.2 Wireless charging techniques 8

3.2. Contactless power transfer using magnetic resonance 8

3.2.2 Optimal system design of the online electric vehicle, utilizing wireless power transmission technology 11

3.2.3 Online electric vehicle 11

3.3 Solar road techniques 14

3.4 Waste and bio-materials 15

3.5 Noise-electricity converting 17

4 Discussion 19

4.1 The conceptual design 19

4.2 On-the-road charging and materials 19

4.3 Social impact of future materials 19

References 21

Green Highway Design

Group 1

1 INTRODUCTION

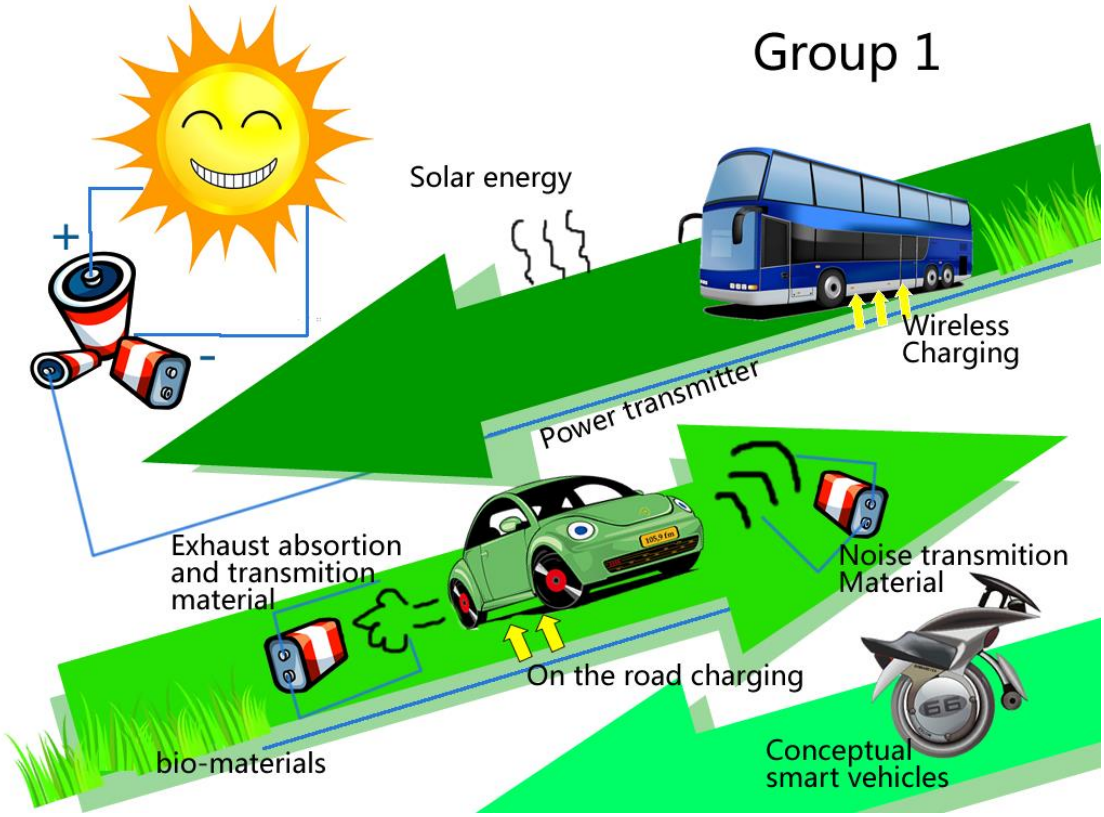

Figure 1 Sketch of the design

As can be seen in Figure 1, there were several ways used to build the road, generate the energy and power vehicles. The aim was to obtain a *Green* and *Healthy* highway. There are strong connection between the road and the vehicles. For the material side, bio-materials are chosen as the basis for the environmental friendly way to build and maintain the infrastructure. As for new technologies, the report goes into solar panel roads, on-the-road charging and noise transition. From the power generated, the group

promotes the use of electric vehicles (EV), as well as designing new conceptual smart vehicles.

2 BACKGROUND

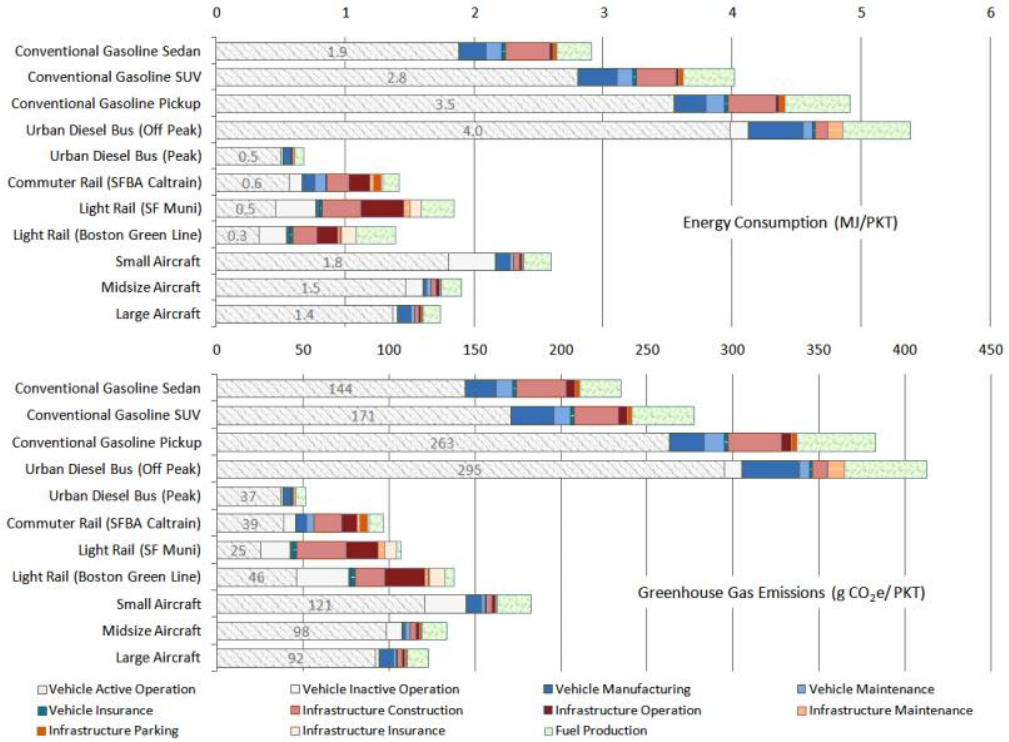

Figure 2 Energy consumption and greenhouse gas emission (Mikhail & Horvath, 2009)

In order to reach the target of green, it is important to know which factors contribute most to the emissions. Figure 2 and Figure 3 show that the dominant contributors to energy consumption and green-house-gas (GHG) emission from the road are the active operational components of vehicles. This suggests that technological advancements to improve fuel efficiency and switching to lower fossil carbon fuels are the most environmentally friendly actions. While energy efficiency improvements are still warranted, coupled with lower fossil carbon fuels in electricity generation, reductions in station construction energy use and infrastructure operation could also have notable effects. Particularly, the reduction of concrete use or a switch to GHG intense materials with lower energy input would improve infrastructure construction performance, while reduced electricity consumption and cleaner fuels for electricity generation would improve infrastructure operations.

SO_2 emissions for all modes are heavily influenced by direct or indirect electricity use. Similarly, significant NO_X emission reductions can be achieved through cleaner

electricity generation as well as the reduction of diesel equipment emissions in transport and material extraction operations.

The reductions could be achieved by decreased or clean electricity consumption, using equipment with cleaner fuel inputs, or through the implementation of improved emissions controls. Automobile CO emissions are mainly from active operation (with a large portion attributed to the cold start phase).

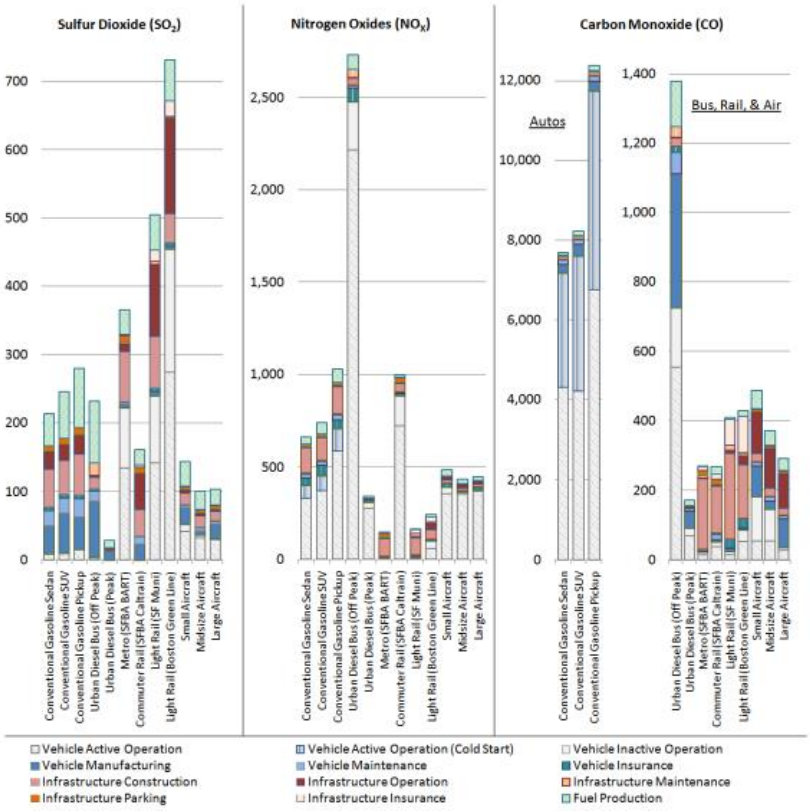

Figure 3 Other emission (Mikhail & Horvath, 2009)

Inputs such as electricity for plugin hybrid electric vehicles could also significantly change several components in this study. Batteries in vehicle manufacturing, differing operational characteristics, and electricity production (especially wind and solar) are just some of the components that would affect the results presented here.

As a result, energy-efficient electrical vehicles, electricity-generate materials and sustainable materials are included in the design.

2.1 VEHICLES

2.1.1 WHY ELECTRICAL VEHICLES?

EVs differ from fossil fuel-powered vehicles in that the electricity they consume can be generated from a wide range of sources, such as fossil fuels, nuclear power and renewable sources such as hydro power, wind power and solar power. During the last few decades, environmental impact of the petroleum-based transportation infrastructure, along with peak oil prices, has led to renewed interest in an electric transportation infrastructure. EVs carbon footprint, the negative impact an EV has on the environment, and other emission varies greatly and is dependent on the fuel and technology used for the electricity generation.

2.1.2 WHY PERSONAL TRANSPORTERS?

Personal transporters, such as the Segway, are smart and portable vehicles that use electricity and human energy for driving. Their main advantages are

- *Relieving congestion* (Liu & Parthasarathy, 2003). These vehicles only need only need a lane width of 1 to 1.3 meters at the most, meaning that a standard 4 meter wide traffic lane can accommodate three lanes of these vehicles. Taking their lower traffic speed into considerations, a standard lane can have a total capacity of about 2400 vehicles per hour.
- *Reduce Gasoline Consumption and Air Pollution*. Environmental benefits can be gained over a period of time if electrically driven vehicles substitute a small percentage of automobiles.
- *Create Livable Communities.* The personal transporter has clear advantages in terms of flexibility and comfort. While most transit systems have been operating on rigid routes and schedules and limited geographic overages, the personal transporter can go beyond them without boundaries.

2.2 ROAD MATERIALS

2.2.1 WHY SOLAR ROADS?

A large part of every developed country is covered by roads. Presently, these roads only have one purpose – supporting traffic that drives on top of them. Utilizing present roads for different purposes can be very beneficial for the society as a whole. One of the most straightforward ideas is to use the roads to amass energy. During the day, the sun shines and warms up the surface of the roads. During the night the roads cool down again. Is it possible to harvest the energy from the times when the sun shines?

2.2.2 WHY NOISE-ELECTRICITY GENERATION?

The most common treatment of traffic noise is to reduce it by porous asphalt or noise walls. However, sound is a mechanical vibration in the form of waves, meaning it

contains energy. Is it possible to convert traffic noise into electricity which can then be used to supply the demand of vehicles driving on the roads?

2.2.3 WHY BIO-MATERIALS?

As future technologies are implemented in the roads, the pavement structure will be affected in different ways. Higher capacity and road efficiency will generate new loading conditions. Technology implemented and merged inside the pavement will change the way pavement is affected by loads and the required life time of a pavement might be longer. It is important to improve the sustainability of the pavement materials at the same time as new green technologies are implemented, and increase the sustainability of the road system as a whole. The future pavement materials should be able to satisfy higher traffic demands, comply with varying technologies inside the pavement structure and contribute to a sustainable road infrastructure.

3 DESIGN IN-DEPTH

3.1 PERSONAL TRANSPORTER: CONCEPT DESIGN

The personal transporter designed for this project is intended to solve the *last-mile-problem* – short distance traveling - with a *green* approach. The transporter is equipped with an effective electric wheel motor and is compatible with wireless charging roads. The carbon fiber material provides a super-lightweight body, ensuring minimal energy consumption. It can be folded into a small circle, making it ultra portable. With standard components 2 to 4 of them can join together and form an electric tricycle or car, adding convenience for a family on holidays. The design is shown in detail in Figures 4-6.

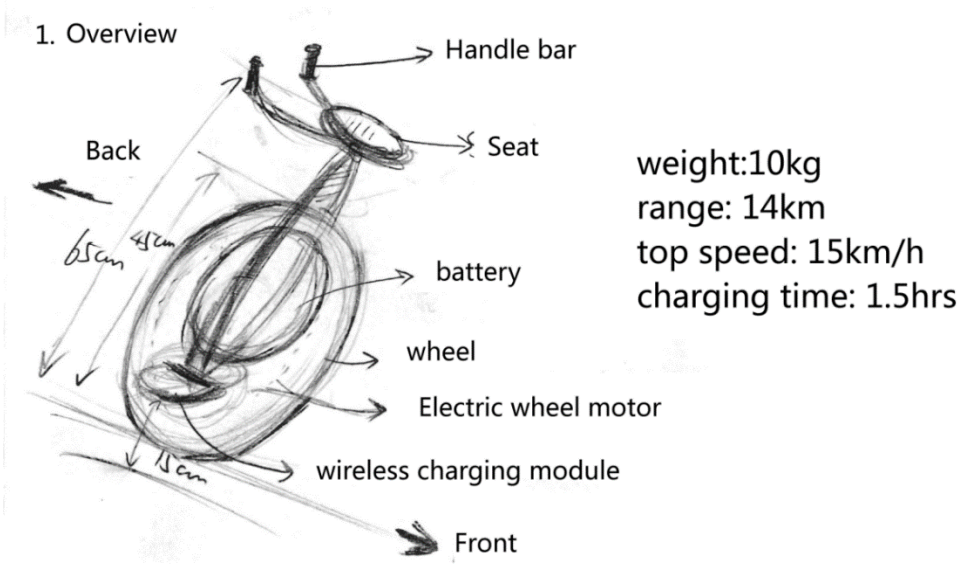

Figure 4 Conceptual design of a personal transporter

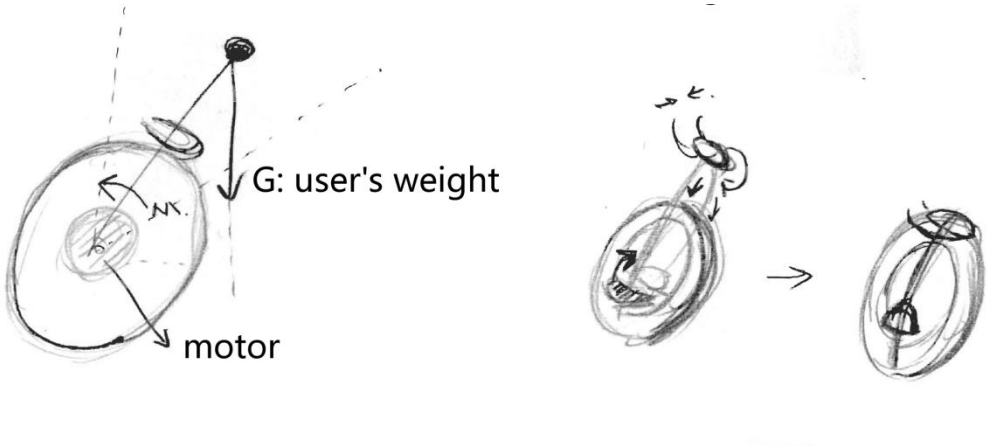

Figure 5 Self-balance and folding design

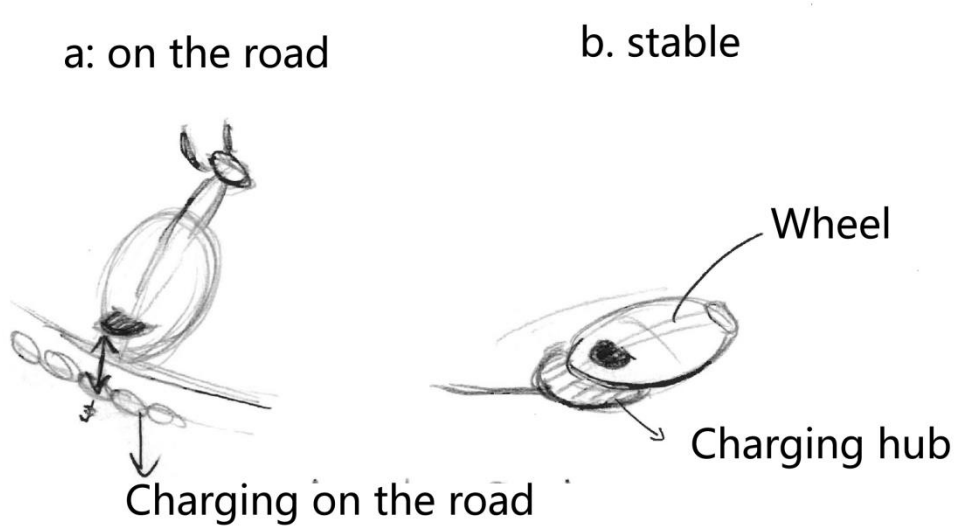

Figure 6 Wireless charging design for a) on-the-road and b) stable charging

3.2 WIRELESS CHARGING TECHNIQUES

On-the-road charging uses the road to charge cars. Using this technology, vehicles can be charged while driving on the road, reducing the need for fossil fuel and large batteries that power modern vehicles. There are two main ways to charge, *static* and *dynamic.* With static charging, the vehicles are charged after coming to a full stop, while dynamic charging indicates that the vehicles are charged whilst they are in motion.

Static charging is an idea that has been developed and implemented at a smaller scale for bus services. One example of use is the campus bus services at the Utah State University (Utah State University, 2012). There, an electrical bus travels the route between stops and while it lets passengers in and out it is being charged. The charging station is an inductive plate that charges the bus wirelessly. Static charging is not ideal for highways, where the design aims at vehicles traveling fast and without stops. Therefore, this technology will not be described further here.

Dynamic charging is less developed and has more unknown factors than the static charging. The technology is implemented by introducing inductive materials, copper or steel for example, into the top layer of the pavement itself.

3.2. CONTACTLESS POWER TRANSFER USING MAGNETIC RESONANCE

A novel solution that does not require the user to connect the batteries to a power source could be Contactless Power Transfer (CPT) (T, T, & Y, 2009). Implementing CPT on a

large scale could add more value to EVs and cause them to to surpass the gasoline vehicle in terms of convenience.

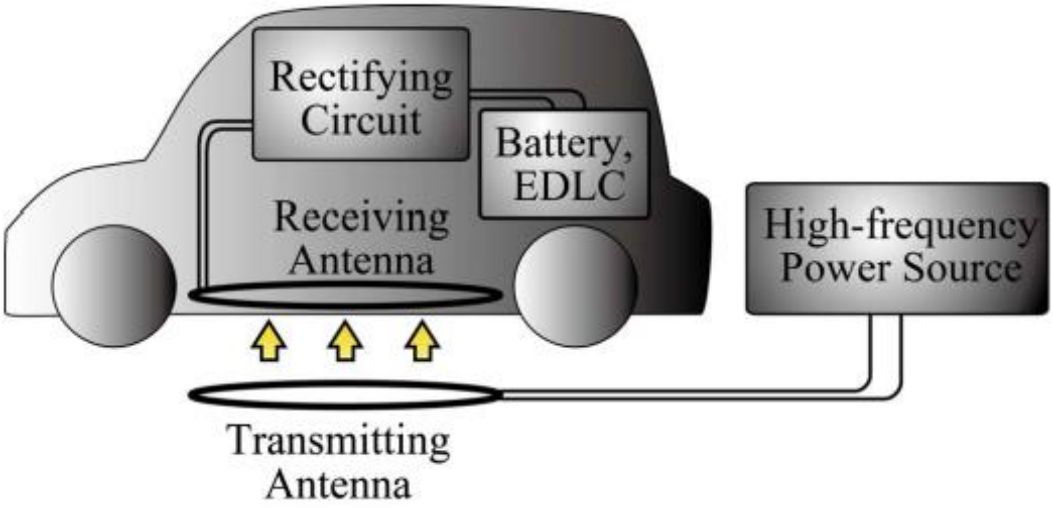

Figure 7 concept of contactless power transfer system for EV (T, T, & Y, 2009)

The contactless power supply system is shown in Figure 7. The system consists of the contactless power supply from a high-frequency power source, a transmitting antenna, a receiving antenna, a rectifying circuit and electric power storage (batteries or electric double layer capacitors [EDLCs]). This project will mainly focus on the antennas.

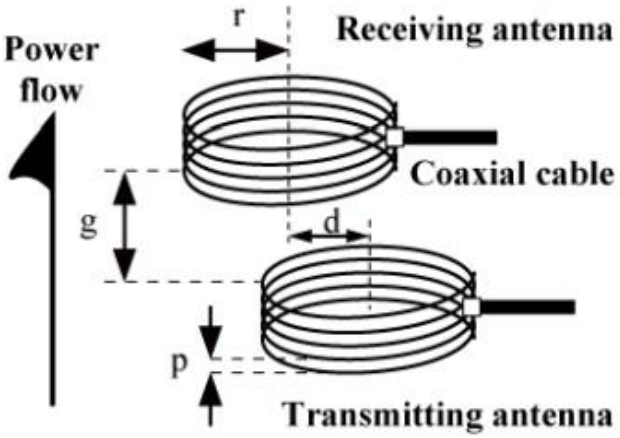

Figure 8 Parameters of the antennas (T, T, & Y, 2009)

In Figure 8, the parameters of the antennas used are shown. The radius of the receiving antenna is denoted with *r* (here *r=150* mm), *g* notates the air gaps between the transmitting and receiving antenna, *d* is the displacement of antennas, *p* is the pitch of the antennas (here *p*=5 mm) and *n* is the turns of the antennas. Here, η11 is the percentage of power reflection and η21 is the power transmission percentage, i.e. the efficiency of the

power transmission. S11 is the coefficient of reflection and S21 is the coefficient of transmission.

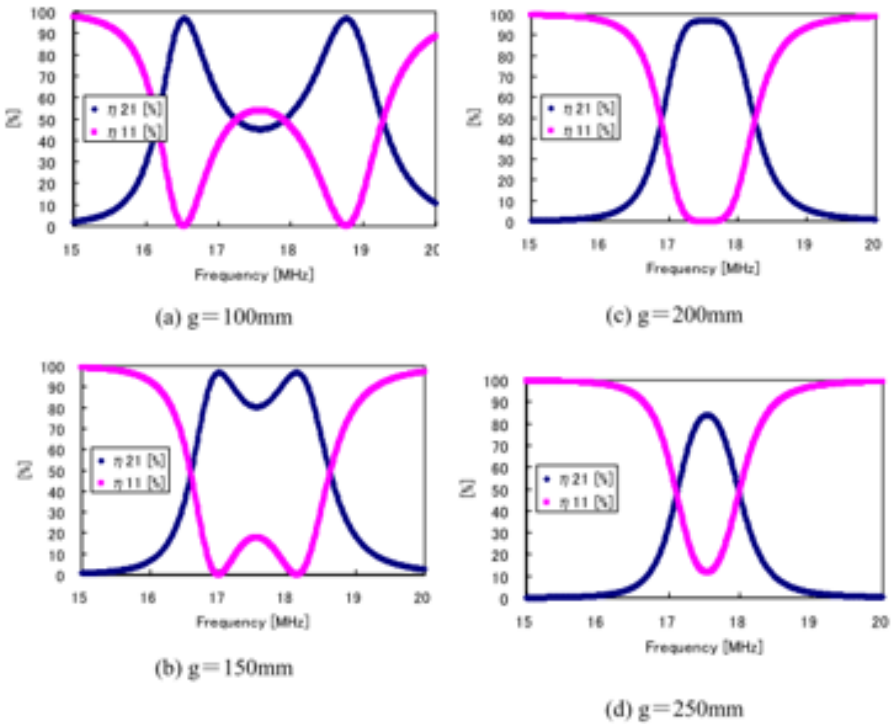

Figure 9 Efficiency with air gaps (Imura, 7-10 Sept. 2009)

Until the numbers of resonance frequencies become one, the maximum value of the efficiency is almost the same and the efficiencies are around 96-97% (Figure 9 (a), (b), and (c)). After the numbers of resonance frequencies are one, the efficiency becomes worse and decreases to zero (Figure 9 (d)).

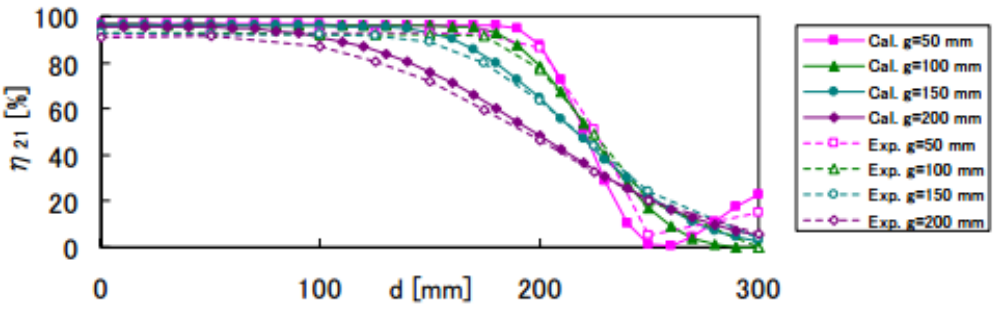

Figure 10 Efficiency with alignment (Imura, 7-10 Sept. 2009)

Figure 10 shows that when the displacement is smaller, the efficiency exceeds 90% for every air gap length. The same is observed when the gaps are short (g= 50mm, 100mm and 150mm) and the displacement is less than 150mm. When the air gap is large (g = 200mm) the efficiency starts to decrease when *d*>50 mm..

The efficiency is higher than 90% when the gap air gap is less than *g*=200 mm at resonant frequencies. The minimum ground clearance of passenger vehicles is between about 90 mm to 200 mm. Therefore, 10 turn antennas provide a wider cover than 5 turn antennas, making 10 turn antennas are more suitable for EVs.

3.2.2 Optimal system design of the online electric vehicle, utilizing wireless power transmission technology

The KAIST OLEV utilizes a resonant coupling technique from a wireless power supply (Ko & Jiang, Sept. 2013). Power from the 60-Hz supply is converted to a frequency of 20 kHz by an inverter, and a current of 200 A flows through the power transmitter; 60 kW of power may be wirelessly transferred from the power transmitters with 80% efficiency (Ko Y. D., 2013). The design is shown in Figure 11.

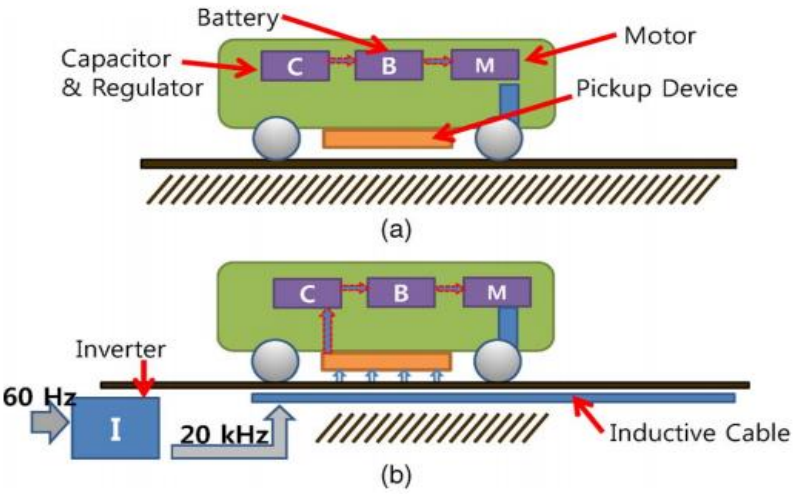

Figure 11 OLEV system. Charging and depleting the energy in the battery. (a) A vehicle is operating on the road where no transmitter unit is installed. (b) A vehicle is operating on the road where the transmitter unit is installed. (Ko & Jiang, Sept. 2013)

3.2.3 Online electric vehicle

The online electric vehicle (OLEV) draws its electric power from underground electric coils without using any mechanical contact (Sun, Cho, & Rim, 2011). The maximum efficiency of power transmission over a distance of 17 cm is 72%. OLEV has a small battery, which enables the vehicle to travel on roads without the underground electric coil. Batteries are recharged whenever OLEV draws electric power from the underground

coils and thus, do not require expensive separated charging stations. The concept is described in Figure 12.

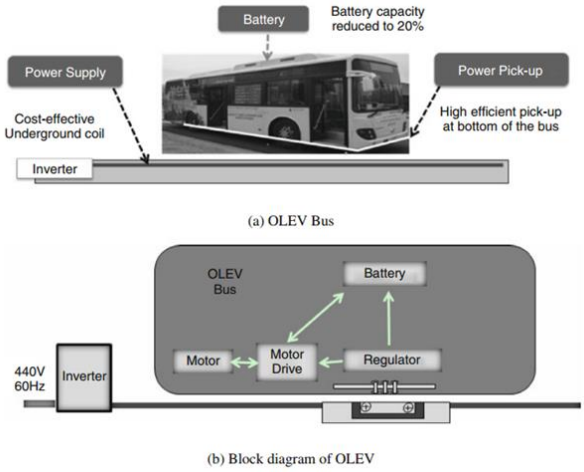

Figure 12 OLEV bus and block diagram (Sun, Cho, & Rim, 2011)

Two basic reasons for developing OLEV buses and cars are to obtain better air quality in large cities and to reduce CO_2 emission and thus slow down global warming. By removing cars with internal-combustion (IC) engines from the streets of major cities, total emission will decrease and air quality will improve. However, the total reduction of greenhouse gases depends on the specific means of electricity generation, which may change more gradually. The use of OLEV may not affect the world's primary energy demand in the short term.

According to Sun, Cho & Rim, 2011 Korea needs to dedicate two nuclear power plants to electricity generation to replace all IC engine cars being used in Korea in 2009 with OLEV car. At the moment, nuclear power plants generate around 40% of electricity generated in Korea, with eight more being built. The cost of electricity is only 22.7% of the cost of fossil fuel in Korea. As many countries in the world do not have any oil reserves, they will have to rely on nuclear power if they are to replace all IC engine cars with OLEV cars and buses, without causing global warming.

To reduce the emission of CO_2, nuclear power plants and renewable energy sources have to be used for electricity generation on a larger scale than is done today. In Denmark, windmills produce about 20% of the electricity used in the country. Until other green technologies for generating electric power are developed, many countries will have to rely on nuclear power. According to the International Energy Commission, the nations

around the world need to build 1750 new nuclear power plants until 2050 to meet the energy needs of the world, about 35 new plants a year.

The number of EV that can be powered by the solar system

There are lots of factors connected with solar energy. At noon, the solar energy is about 100W/m^2.

By using a theoretical design for the imaged city Beikholm it is assumed that:

- The area of Beikholm is 10^4 km^2=10^{10} m^2
- The sun shines for 4 hours and the energy density is 100 W/m^2=0.1 kW/m^2
- 10% of the area of Beikholm is used to absorb solar energy
- The transfer efficiency of solar to electric is 20%

Therefore, the theoretical electricity generation can be calculated as:

- $W = 10^{10}\ \mathrm{m}^2 \times 0.1 \times 0.1\ \mathrm{kW/m}^2 \times 4\mathrm{h/day} \times 0.2 = 8 \times 10^7 \mathrm{kWh/day}$
- The S30 EV, designed at Dongfeng Motor Corporation, requires 13.8 kWh/100 km = 0.138 kWh/km
- Therefore, the theoretical driving distance per day can be

$$l = \frac{8 \times 10^7\ \mathrm{kWh/day}}{0.138\ \mathrm{kWh/km}} = 580 \times 10^6\ \mathrm{km/day}$$

- Assuming each car drives 100 km/day

$$l = \frac{580 \times 10^6\ \mathrm{km/day}}{100\ \mathrm{km/day}} = 5.8 \times 10^6\ \mathrm{cars}$$

- Which means that by harvesting the sun's power it is theoretically possible to generate enough energy to power the whole car fleet of the city

3.3 SOLAR ROAD TECHNIQUES

One way of harvesting the solar energy is to install solar panels as the top layer of the roads. Today, most solar panel farms are large structures, placed in remote deserts or in areas that could be occupied by something else. Modifying existing infrastructure to generate power thus saves space, since no new structures have to be built, and energy previously wasted is put to use.

A US based company (Solar Roadways, 2013), has been developing solar panel roads for several years. As of now, a structure has been developed and prototypes have been built. Testing has not yet reached a practical level, although a solar powered parking lot is expected to be built before the end of 2013. The structure of the top layers can be seen in Figure 13.

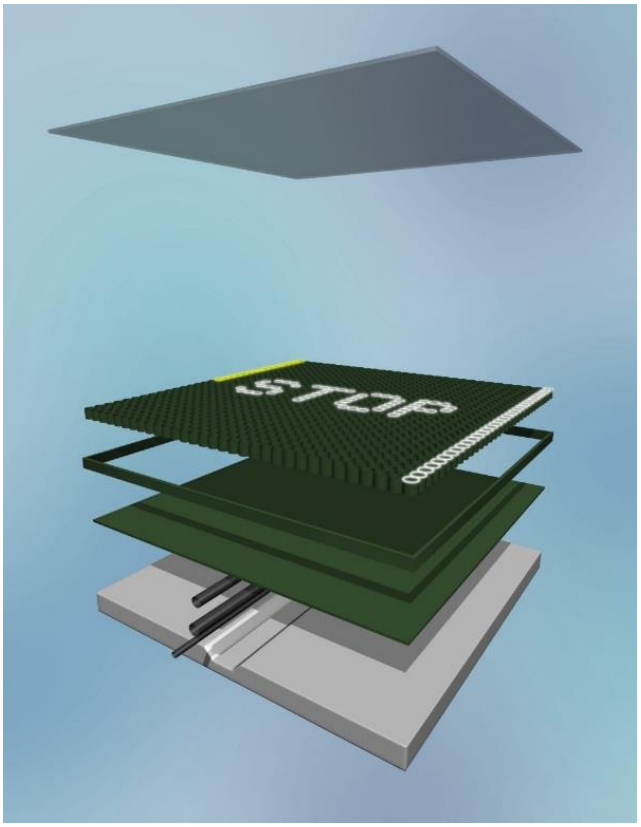

Figure 13 - Structure of solar panel roads. (Solar Roadways, 2013)

As can be seen in Figure 13, each panel is put together by three parts.

- Top layer is the road surface layer. It is translucent, clear enough to let sun shine through while at the same time is not reflective. The layer is somewhat rough, to create friction between the road and tires. It is also equipped with a heating element -which uses harvested energy to keep the surface frost free – and led lights to use when necessary.

- The middle layer is the electronics control layer. It can measure loads and surface temperature and controls the heating element according to conditions.
- The bottom layer is the base plate layer. In it are cables, which distribute the power harvested in the layer above throughout the road network. The layer is weatherproof and protects the layer above.

Since the solar panel roads are still at a conceptual stage, there are many unanswered questions. Disadvantages might outweigh the advantages and a feasibility study concerning financial matters does not seem to have been performed. Even when cost, both initial and due to maintenance, there are many concerns.

The first concern is the structural capacity of the top layer. According to the developers the top layer can withstand heavy trucks, but at the time of writing no data is available to back that claim up. Another issue is the reflectiveness of the top layer. Although the developers claim about 15% effectiveness of the solar panels, it is not certain that claim is based on anything real. For one, by assuming an average of 12 hours of sun shine per day (50% of each day); really heavy traffic (cars leaving little to no space between each other) causing no solar energy harvesting for two hours each day (8% of each day); account for snow covering the road 2 months a year (8% of the year); only assume 50% harvesting during rainy days with Stockholm's average number of rainy days being 173 per year (withdrawing another 25%); that leaves only 9% effectiveness and that's without taking into account that the surface layer might get damaged and its translucency would decrease. The effectiveness of the whole system and how the energy is used or stored is also a matter that has not been addressed. The sheer number of unanswered questions indicates that although the idea might become reality, it is not something that will happen just yet. In the meantime, the developers, Solar Roadways (Solar Roadways, 2013), will, with the support of the US Department of Transportation, continue to evolve the idea and, hopefully, address the issues at hand to make the solar panel roads a reality.

3.4 WASTE AND BIO-MATERIALS

To provide more sustainable materials used for road construction, current fossil fuel dependent materials have to be modified or replaced. Bituminous binders are a finite resource and uses high amounts of energy for production as well as contributing to greenhouse gases.

Some waste and bio-materials have properties similar to the ones of conventional asphalt binders when they have been processed (Iowa State University, 2010) (Williams & Raouf, 2011) (Fini, o.a., 2011). Instead of mining for new material, materials that would otherwise have been placed as landfill or combusted could be modified and used

to create new pavement materials. Materials based on plants and vegetation could also provide a source for new road materials.

Bio- and waste materials are emerging, both as part of full scale tests and laboratory test (Andersen, o.a., 2011) (Williams & Raouf, 2011). Vegetable oils, manure and fish oil are examples of such materials.

The method of creating bio and waste substitutes is similar to the process of creating asphalt from crude oil (Wikipedia, 2013). Pyrolysis is used to separate the different chemical compounds of a material allowing chemicals with similar properties as conventional binders to be produced.

New bio and waste materials can be used in different ways for the asphalt layer in the pavement. Some materials work as an additive which is increasing the conventional binder properties and others completely replace conventional binders. Materials which change the binder properties work in different ways. Some materials decrease aging of the binder thus allowing the asphalt to maintain its original properties for a longer period of time (Tongyan, 2013). Some substitutes can also be diluted in current binders with the aim of maintaining material properties and decrease the use of crude oil binder (Ecopave, 2009).

3.5 NOISE-ELECTRICITY CONVERTING

One way to convert noise into electricity is by using the Soundscraper, a 100 m tall conceptual tower designed by French scientists (ARZATE, 2013). The Soundscraper takes advantage of a city's noise pollution by capturing airborne sound and converting it into usable energy. One of the most abundant energy sources is ambient motion. Vibrations can provide plentiful energy, and can be transferred through a number of media, making this form of kinetic energy very practical.

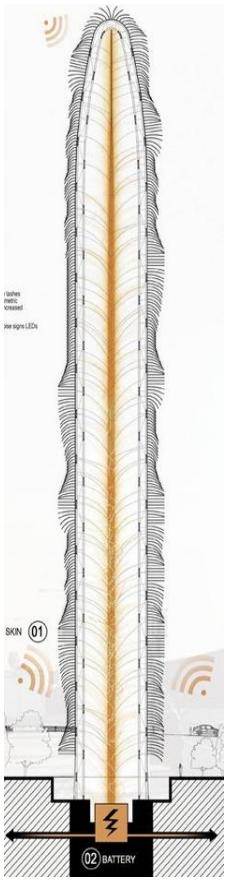

Figure 14 A sketch of the Soundscraper

(ARZATE, 2013)

The Soundscraper is located next to a main traffic infrastructure, mostly outside of city centers, where noise pollution is at its maximum. Motorway junction and railway hubs represent a no man's land in the urban territory and are thus the areas with the greatest potential for energy harvesting.

The Soundscraper‘s façade vibrates depending on the intensity and direction of urban noises. The Soundscraper‘s skin - electro active lashes supported by a light metallic structure - forms the exterior of the building and provides maximum exposure to city noise. Covering a wide spectrum of frequencies, this noise includes vehicular traffic,

pedestrians, trains, building inhabitants and even aircraft passing overhead. Around 84000 electro-active lashes are integrated throughout 100 m tall tower. The lashes are covered with sound sensors PFIG (Parametric Frequency Increased Generators). A specialized PFIG energy harvester convert sounds vibrations caused by surrounding noises to capture kinetic energy, after which an array of transducer cells - employing a novel actuation method - are used to convert the mechanical energy into electricity. The electrical current is then transferred to a main storage compartment to be redistributed to the city. Based on scientific researches results, one tower could produce up to 150 MW/h, representing 10 % of urban lighting consumption of the city of Los Angeles. At the same time, this renewable energy could contribute to the reduction of CO_2 emission.

Another concept, designed by Korean researchers, is a replica of a human ear-drum which absorbs sounds and converts into electricity. It is named SONEA and its dimensions are a 45 cm (length) by 45 cm (width) by 8 cm (thick), weighing 7 kg with Poly Carbonate elements, ABS plastic and some other chemical components inside. The vibratory drum bionic shock, caused by noise, can be converted into chemical energy which is then stored within the unit. When the box is connected to electrical appliances, the energy will be released as electricity. SONEA can convert 30 watts of power per decibel of sound it intercepts (Burns, 2009).



Figure 15 A sketch of the SONEA (Burns, 2009)

Both concepts introduced in this chapter are still at an early stage. It is possible that these ideas are not possible in the foreseeable future due to technological challenges. However, these concepts introduce very green technology and fall well within the scope of this project.

4 DISCUSSION

In this design report, the main objective was to find a link between innovative technology and the authors' fields of study. Many of the concepts introduced here are still at a very early stage and therefore require further studies before they can become feasible options. It is the belief of the authors that these concepts are the most exciting technologies that are available in the next 10-15 years and that some of them might become a dominant option for nations around the globe.

4.1 THE CONCEPTUAL DESIGN

The personal transporter, the solar panel roads and the noise-electricity converting are the conceptual design which needs more mature techniques and further research before becoming reality.

4.2 ON-THE-ROAD CHARGING AND MATERIALS

There are many possible disadvantages with on-the-road charging. When introducing new material into the asphalt layer, it might affect the bonding within the pavement and change the structural capacity. That could lead to more rutting, cracking and early failure. However, according to the industry mentor Per Redelius at Nynäs AB, research indicates that introducing steel and copper into the pavement might have positive effects on its health and even extending its lifetime. The steel and copper are introduced to maximize the efficiency of the charging, since they are good conductors. Copper and steel are expensive and it is possible that the initial cost will never be recovered during the lifetime of the road. The cost has to be researched for every project in order to make a decision about the feasibility. A third disadvantage, possible the most important one, is the affect it might have on human health. If, for example, a person with a pacemaker is inside a car that's being charged on the road, will it affect the pacemaker? More studies have to be carried out in order for this technology to advance to a realistic stage.

4.3 SOCIAL IMPACT OF FUTURE MATERIALS

It's important to study new alternative binder materials from a life cycle perspective. While the life cycle analysis of a material might prove to have significantly positive results, it's also important to address the social impact of future materials. A material might be sustainable but it might also create a demand for the material which did not exist prior to its usage. For example, the need of farmland for an agricultural purpose might have a higher importance than replacing the crops with plants to grow biomaterials for roadways. Waste materials produced in large quantities are something

that should be investigated further. If a viable waste material is found, the new material will serve a purpose as well as transforming the cost of handling the waste to a source of income when it's used to pave new roads.

REFERENCES

AndersenE, VasudevanJ, StokerD, HagenE, BragstadR, & LerfaldB O. (2011 April ,15.). Road trials with vegetable oil based bitumen in Norway. Accessed: 2013 December ,7.URL: http://trid.trb.org/view.aspx?id=1100143

ARZATECARLOS. (2013 March ,12.). Soundscraper Captures Sound Kinetic Energy while Reducing Noise Pollution. Accessed: 2013 12 ,10.URL: eVob: http://www.evolo.us/competition/soundscraper-captures-sound-kinetic-energy-while-reducing-noise-pollution/

Avello Bioenergy. (2013). Bioasphalt® binder. Accessed: 2013 December ,7.URL: http://www.avellobioenergy.com/en/products/bioasphalt_binder/

Burns, C. (2009). *SONEA Converts Sound to Energy*. Retrieved 12 10, 2013, from http://www.yankodesign.com/2009/09/09/sonea-converts-sound-to-energy/#5o5tId7OkxtOFoIY.99

COLAS. (2013). PRODUCTS INTERNATIONAL. Accessed: 2013 December ,7.URL: http://www.colas.com/en/innovations/products/products-international/products-results-1100394.html

Ecopave. (2009). What is GEO320 MRH. Accessed: 2013 December ,7.URL: http://www.ecopave.com.au/bio_bitumen_asphalt_concrete_research_ecopave_australia_002.htm

Ecopave. (2009). What is GEO320 MRH. Accessed: 2013 December ,7.URL: http://www.ecopave.com.au/bio_bitumen_asphalt_concrete_research_ecopave_australia_002.htm

energysolar. (2013). Solar Power Panels. Accessed: 2013 12 ,10.URL: solar energy: http://solarenergy.com/solar-technology/solar-world/solar-power-solar-energy-what-it/

FiniH.Elham, KalbererW.Eric, ShahbaziAbolghasem, BastiMufeed, YouZhanping, OzerHasan, & AurangzebQazi. (2011). Chemical Characterization of Biobinder from Swine Manure: Sustainable Modifier for Asphalt Binder. JOURNAL OF MATERIALS IN CIVIL ENGINEERING(23), 1506-1513.

GuarinAlvaro, AliButt, AbdullahKhan, BjörnBirgisson, & NicoleKringos. (2013). FORENSIC INVESTIGATION OF SURFACE DRESSINGS FAILURE IN ICELAND. Stockholm: KTH.

ImuraTakehiro. (7-10 Sept. 2009). Basic Experimental Study on Helical Antennas of Wireless Power Transfer for Electric Vehicles by using Magnetic Resonant Couplings. Vehicle Power and Propulsion Conference, (page 936 - 940).

Iowa State University. (2010). Bioasphalt® developed at Iowa State to be used, tested on Des Moines bike trail. Accessed: 2013 December ,7.URL: http://archive.news.iastate.edu/news/2010/oct/Bioasphalt

KoDaeYoung. (2013). The Optimal System Design of the Online Electric Vehicle Utilizing Wireless Power Transmission Technology. IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, vol. 14.

KoDY, & JiangJY. (Sept. 2013). The Optimal System Design of the Online Electric Vehicle Utilizing Wireless Power Transmission Technology. Intelligent Transportation Systems, 1255 - 1265.

LiuRongfang, & ParthasarathyRohini. (2003). SegwayHuman Transporter (HT): Potential Opportunities and Challenges for Transportation Systems. TRB 2003 Annual Meeting. TRB.

MikhailChesterV, & HorvathArpad . (2009). Environmental assessment of passenger transportation should include infrastructure and supply chains. Environ.

RoadwaysSolar. (2013). Solar Roadways. Accessed: 2013 12 ,10.URL: Solar Roadways: http://www.solarroadways.com/intro.shtml

Shell. (2013). Shell Floraphalte. Accessed: 2013 December ,8.URL: http://www.shell.com/global/products-services/solutions-for-businesses/bitumen/products/shell-floraphalte.html

ShengTang. (2010). Asphalt modification by utilizing bio-oil ESP and tall oil additive. Iowa: Iowa State University.

SunPN, ChoPD, & RimTC. (2011). Design of on-line electric vehicle (OLEV). Global Product Development, 3-8.

TImura , TUchida , & YHori. (2009, 3(2009)). Flexibility of contactless power transfer using magnetic resonance coupling to air gap and misalignment for EV. World Electric Vehicle Journal, 24-34.

TongyanPan. (2013). Coniferyl-alcohol lignin as a bio-antioxidant for petroleum asphalt:. Fuel(113), 454-466.

UniversityStateIowa. (2013). Iowa State University, 2010. Bioasphalt® developed at Iowa State to be used, tested on Des Moines bike trail. .

UniversityStateUtah. (2012 Nov ,15.). Utah State University Unveils Wirelessly Charged Electric Bus. Accessed: 2013 12 ,10.URL: Utah State University: http://www.usu.edu/ust/index.cfm?article=51862

Wikipedia. (2013 October ,25.). Bioasphalt. Accessed: 2013 December ,7.URL: http://en.wikipedia.org/wiki/Bioasphalt

Wikipedia. (2013 December ,5.). Fractional distillation. Accessed: 2013 December ,7.URL: http://en.wikipedia.org/wiki/Fractional_distillation

Wikipedia. (2013 December ,3.). Pyrolysis. Accessed: 2013 December ,7.URL: http://en.wikipedia.org/wiki/Pyrolysis#Biofuel

WilliamsR.Christopher, & RaoufAbdelMohamed. (2011). General Rheological Properties of Fractionated Switchgrass Bio-Oil as a Pavement Material. Road Materials and Pavement Design(11), 325-353.