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# ELECTRIC VEHICLE CHARGING STA- TION

Global Analysis of EVCSs and their Power Source

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## ABSTRACT

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The issue of global warming due to emission of greenhouse gas (GHG) from the fossil fuel powered transport system and other sources gave the impetus to re-research alternative means to power the transport system without fossil fuels. Upon various findings and research, the Electric Vehicle appears to be the likely alternative for the fossil powered vehicles. The desire to research deep into these technology grew stronger and therefore was chosen as thesis topic.

This thesis discusses the availability of public charging stations around the globe and their primary electrical power source by analyzing a few selected countries around the globe based on their electric vehicles and charging infrastructure policies. The aim was to firstly, ascertain the easy accessibility of public charging stations by electric vehicle owners which will give impetus to the performance of the electric vehicle in the global market. Finally, to investigate the mode of generating the power probably been used by the charging stations.

The study employed a method of country analysis on Electric Vehicle Charging Station (EVCS) policies and the main mode of power generation in those countries. The analysis includes a number of EVCS projects in the country, projects includes planned, in progress and functional projects and the - primary energy source of power generation, – fossil or renewable. It was discovered that most developed countries have massively invested into R&D of EVCS and are aiming to increase the number of electric vehicles on their roads. Nevertheless, the mode of generating power (for charging the electric vehicles) in these countries is mostly by fossil source, which raises the issue of possible CO<sub>2</sub> transfer instead of reduction.

Keywords      Range anxiety, Electric Vehicle

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## **ABBREVIATIONS**

EVCS	Electrical Vehicle Charging Station
SAE	Society of American Engineers
CCS	Combined Charging Standard.
ICE	Internal Combustion Engine
NPE	Nationale Platform Elektromobilitat
DBEDT	The Department of Business, Economic Development and Tourism
NRG	An American large energy company
DfT	Department of Transport (UK)
SGCC	State Grid Corporation of China
CSPG	Southern Power Grid Company
PEV	Plug – in Electric Vehicle
BEV	Battery Electric Vehicle
PHEV	Plug – in Hybrid Electric Vehicle
PIP	Plug-in places
E Mobility	Concept of using electric powertrain technologies.
ECotality	An electric transportation and storage tech. comp.
MINI E	Electric car demonstration organized by BMW.
HOV	High Occupancy Vehicle.



## 1. INTRODUCTION

An electrical vehicle (EV) is an alternative technology for the future road transportation and partial solution for the global warming crisis. The willingness of customers to accept and trust in electrical cars depends on various factors namely; cost competitiveness, range, life span, overall performance, the rate and convenience of charging, availability of fast charging stations among others.

It is estimated that 50% of the crude oil production is utilized only by the transportation system; the high consumption of liquid fossil fuel increases the concentration of (GHG) in the atmosphere and in particular carbon dioxide /21/. The introduction of electric car into the market as a way to reduce global CO<sub>2</sub> emission and climate change mitigation is an opportunity for electric companies around the globe to increase annual production to meet the demand of the market. The prerequisite for the large scale promotion and usage of electric vehicles is mass construction of EV charging infrastructure network /1/. As fuel filling stations are needed to refuel convectional cars, so are charging stations needed to provide the needed power for electric vehicles on the road /1/.

An Electric Vehicle (EV) charging station or recharging point, sometimes called charge point is an infrastructure that supplies electricity for recharging electric vehicles. The types of charging station differs but serves the same purpose. The need for more charging infrastructure is highly necessary as battery electric vehicle ownership is increasing. The charging station may be an on-street facility owned by electric utility companies or at retail shopping centers run by private companies.

The number of charging stations around the globe has increased recently with more to immerge in the future. Some countries are leading in the campaign for more electric vehicle charging infrastructure. The charging power for charging infrastructures is analyzed based on the method of production – whether conventional or renewable source is used. The importance of this topic cannot be under-

played since it gives the overall picture of current situation of the prerequisite for public acceptance of electric vehicles which is viewed as the alternative technology for conventional internal combustion engine vehicles in the campaign of GHG emission reduction and climate change mitigation. The study also seeks to point out that, CO<sub>2</sub> might just been transferred from vehicles to power plants with little or no reduction at all.

### **1.1 The Research Objectives and Problem Definition**

The objective of the research is to investigate the current state of EVCS globally , the performance of selected countries so far as EVCS is concern, the existing mode of generating power; primary source of energy - fossil or renewable - and the possible future trend of electricity generation.

### **1.2 Research Problem Definition**

The research is not for any client but the topic is chosen in the spirit of addressing the current issue of global warming which could be mitigated to a certain limit if the electric vehicle market expands competitively against internal combustion engine (ICE) vehicles which also depends on easy access to or readily availability of EVCS to electric vehicle customers. Currently, the number of EVs on the road is almost negligible compared to ICE vehicles due to their high prices and unsatisfactory performance, especially their limited range drive. In order to replace ICE vehicles completely with EVs, it is essential to improve their range and provide adequate charging infrastructure across the globe. /3/ Furthermore, the principal aim of introducing electrical vehicle is the reduction of greenhouse gases emission which may be defeated if most EVCS are been powered with fossil generated electricity.

### **1.3 Problem Definition and Research Question.**

The research questions are summed up in the various analyses, the entire report is written based on the answers to the questions.

Q1. How many EVCSs are in the selected countries?

Q2. What is the primary energy source at the power generating plant?

#### **1.4 The Structure of the Study**

The structure of the study is drafted by describing the general concept of EVCS in Chapter 2, detailing the various components, arrangements and types. Chapter 3 elaborates on the various country analyses and their EVCS status, types and suppliers.

Chapter 4 discusses the selected countries policies on EVs and charging stations. Chapter 5 discusses the mode of power generation in the selected countries, comparing all the primary energy sources and the main source employed by each country. Chapter 6 comprises the summary, recommendations and conclusions.

#### **1.5 Research Methodology.**

The qualitative method was employed to gather information in this study. The study has been organized as desktop information gathering concerning EVCSs architecture, the selected countries before performing the analysis. The table list of EVCSs in the selected countries is obtained from various scientific articles referred while other scientific materials were reviewed.

The selected countries were analyzed based on their EVCS capacity. The selected countries were Germany, Estonia, Switzerland, UK, France, China, Israel, and the USA. The analysis of the two primary energy sources was carried out after the needed information had been gathered.

## **2 THE GENERAL CONCEPT OF EVCS INFRASTRUCTURE**

The rapid growth of electric vehicles in the market and the trend of the motor car industry demand equally proportional and adequate charging facilities around the globe if electric vehicles have really come to stay. Many of the charging stations are provided and operated by electric utility companies or by private companies.

An Electric Vehicle Supply Equipment, also called electric vehicle charging station, EV charging station, charge point, charging point or electric recharging point is an infrastructure that supplies electric energy for recharging electric cars or vehicles. A charging station and a convectional gas station are almost similar but the charging station provides energy for electrical vehicles (EV) rather than fuel to internal combustion engine cars. The EVCS infrastructure can be categorized based on the constructional design and the feature arrangement of the charging process. The various types of EVCS infrastructure design arrangement are presented below.

### **2.1 Residential Charging Stations (Level 1 Chargers)**

When owners of electric vehicle return home, the car is plugged in and recharges overnight. The home charging station can be wall - mounted chargers with no user authentication and metering may require the wiring of a dedicated circuit.

### **2.2 Charging While Parked (Level 2 Chargers)**

Some owners of car parking lot in partnership with commercial ventures offer free charge while parked. This type of charging station may be higher speed or slow and it entices EV owners to park and recharge their car while using nearby facilities. This station includes parking at malls, train stations, small centers, parking stations and companies own employees.

### **2.3 Battery Swap**

For speed and convenience, batteries are swapped at vantage points. EV battery swap increases the battery capacity and the capability of handling. The swapping takes approximately 15 minutes and this increases the range of the car.

### **2.4 Fast Charging at Public Charging Station (Level 3 Chargers)**

Fast chargers may be at designated points to permit longer distance trips. These chargers deliver over 100km of range in 10 – 30 minutes. Some examples are; SAE CCS Chargers, CHAdeMO and Tesla Superchargers. The fast charging technology is the ideal technology for general acceptance of EVs. /7/. In this report public fast charging stations are considered.

#### **2.4.1 The Concept of Fast Charging Stations.**

The design of the fast charging electric vehicle infrastructure is based on the following concept; the fast charging infrastructure may consist of 20 stations which are altogether connected to a national grid through a transformer. An aluminum or copper strip bus bar is connected to the transformer which conducts and distributes electrical power to the various stations evenly. An AC / DC or a DC / AC converter is required to convert the voltage to the correct DC voltage level needed to charge the EVs. /7/

#### **2.4.2 General Operation of Fast Charging Station**

The operation of the fast charging stations is similar to that of fuel filling station; one delivers electrical power while the other delivers liquid fuel or gas. Electrical power from the generating plant is fed into the grid. The grid delivers AC voltage to the transformer which boosts the voltage to the required level and delivers it to the bus bar. The bus bar acts as a common rail of an IC engine by distributing the voltage equally to the various charging stations. Since DC voltage is needed to charge the EV batteries, depending on the arrangement of the EVCS, an AC/DC

or DC/DC converter is fitted in the charging spot to convert the voltage to the required level to charge the EVs. There are two possibilities for charging of electric vehicles. /11/

- The use of three phase AC current and conversion to DC inside the car.
- Transferring DC current to the vehicle with the suitable voltage level for the battery.

### **2.4.3 General Construction of EVCS.**

As mentioned earlier, EVCS may consist of the following electrical components or devices.

- ❖ Grid
- ❖ Transformer
- ❖ Circuit breaker
- ❖ Bus bar
- ❖ Converters AC/DC or DC/AC.
- ❖ Filters
- ❖ Battery bank.
- ❖ Chargers

### **2.4.4 The Grid.**

An interconnected wiring or network is used for delivering electrical power from the producers (suppliers) to the clients (consumers). The grid comprises high – voltage transmission lines that convey power from distance sources to demand areas and distributions for individuals. Power plants may be situated at a dam site, they may have a fuel source, alternative energy source (wind, sun, bio-energy) to generate power, the voltage of which is stepped up for the transmission network.

The power is moved over long distances by the transmission network until it reaches its wholesale customer. At the substation, the power is then stepped down

from high transmission voltage to a low distribution level voltage. The power enters the distribution wiring once it leaves the substation, finally it arrives at the service station where it is further stepped down from the distribution voltage to the recommended service voltage ready for consumption.

#### **2.4.5 The Transformer**

A transformer is an energy coupling device that receives electrical energy from a source at a voltage and steps it up or down to another voltage. As mechanical gear train is needed between two drives to change the speed or torque of input and output shafts, likewise, a transformer is needed in electrical circuits to alter voltage levels to suit the intended purpose. A transformer works on the principles of electromagnetic induction which is the process by which series of conductor (coil) magnetically induces voltage into another conductor (coil) located in very close proximity to it.

In this report only a single phase transformer is considered. A transformer basically consists of two electrical coils of wire (conductor), primary winding and secondary windings. These two coils are wrapped together around a magnetic iron circuit called the core. Through the core, the two coils are magnetically linked together allowing electricity transfer between them.

A magnetic field is developed around the primary winding whenever current passes through it which induces a higher voltage into the secondary winding. The input voltage supply is normally feed into the primary windings and it produces magnetic field while the secondary windings convert this alternating magnetic field into electricity thereby producing the needed output voltage.

A single phase transformer operates to either boost or decrease the voltage applied to the primary windings. Whenever a transformer is used to boost the voltage in its secondary windings, it is called a step-up transformer. When it is used to decrease the voltage on the secondary winding with respect to the primary it is

called a step-down transformer. A third type exists where a transformer produces the same voltage on the secondary as on the primary. This type of transformer is called an Impedance Transformer. The difference in primary and secondary winding voltage is resulted by arranging a greater number of turns of secondary windings than that of primary windings.

When voltage is applied to the primary coil, current passes through the coil which produces magnetic field around the coil, called mutual inductance, and the magnetic field strength increases as the current flow arises to maximum value. As the magnetic fluxes expand outward from the coil, the iron core forms a path for the magnetic flux. This magnetic flux links the two windings under the influence of AC supply. The flowing of the flux around the soft iron core, they flow through the turns of the secondary windings, thereby causing a voltage to be induced into the secondary coil. /13/

#### **2.4.6 The Circuit Breaker**

A circuit breaker is a self-operated electrical switch used to protect an electrical switch from damage caused by short circuit or overload. It works by detecting an electrical fault condition and interrupts the flow of current. A circuit breaker differs from a fuse by its ability to reset itself either manually or automatically. When a fault is detected, the circuit breaker contact opens to interrupt the circuit. Springs or compressed air contained within the circuit breaker is used to separate the contact; some of the needed energy sometimes can be obtained from the current itself.

In large breakers, solenoids are used to trip the mechanism, and electric motors are used to replace the energy back to the springs but smaller circuit breakers may be manually operated. Arcing is generated when a current is interrupted and this causes erosion of the contacts and thereby limiting the service life of the circuit breaker. The arc must be controlled in a way so that the contact gap can withstand the voltage in the circuit.



### **2.4.7 Bus bar**

Electrical power distribution to the various charging stations is done by a metallic strip or bar that receives the electricity from the transformer when the grid is supplying or conducts electricity from the battery bank when the grid is not supplying and efficiently distributes it to the various charging stations. The material used for the bus bar determines the amount of current that it can safely carry.

The bus bar comes with different shapes and sizes, examples of common shapes are flat strip, solid or hollow tubes, solid bars and rods, and braided wire. The shape affects to large extent the heat dissipation qualities of the busbar. They may be enclosed or exposed depending on the condition they are being applied. They have to be sufficiently rigid to withstand its weight, mechanical vibration, precipitation and earthquakes. They may be insulated on insulators, otherwise completely surrounded by insulation. The bus bar may be mounted by bolting or clamped.

A fast charging station may contain about 30 charging spots receiving power from one (1) transformer which means power should be distributed to the various charging spots by the aid of a bus bar. The bus bar is intermediate between the transformer and the charging spots.

### **2.4.8 AC/DC Converters**

AC/DC converter is an electrical device that converts an alternating current (AC) to direct current (DC) with one way flow, this is termed as rectification and such converters are called rectifiers. These converters uses diodes of various forms including vacuum tube diodes, mercury-arc valves, semiconductor diodes, copper and selenium oxide rectifiers, silicon-controlled rectifiers and silicon-based semiconductor switches. Silicon semiconductor devices such as thyristors or other controlled switching solid-state switches are used in high voltage direct current power transmission. Rectifiers can be used for many purposes but are often used for

components of DC power supplies and high voltage direct current power transmission systems.

Since the national grid generates AC voltage, which cannot be used to charge the car battery, it needs to be converted to DC voltage to suit the car battery system. AC/DC converters are therefore employed to convert the charging station transformer AC voltage to DC voltage to charge the electric cars.

#### **2.4.9 Battery Bank**

The charging voltage needed to keep the station running or operating should be available all time irrespective of the grid condition. This condition can be made possible by having a battery bank arranged in a different department of the charging station. A battery bank is a series of batteries connected together thereby increasing the voltage, amperage or both for a common application or purpose. The energy available on the national grid may fail due to technical malfunctions along the supply chain. When this occurs the battery bank acts as a backup mechanism to sustain the operations of the charging stations /11/

Batteries can be connected in two ways, namely series connection and parallel connection.

- Series connection connects the voltage of the batteries together but the current ratings is same. For example, two 12 volts, 20Ah batteries connected together in series will produce 24 volts, but still with a total capacity of 20 Amps. The series connection is done by connecting the negative terminal of one battery to the positive terminal of the other battery by means of a suitable cable (jumper cable), this negative-positive connection is applied to as many batteries available in the bank. Another set of cables connects the open positive and negative terminals to the application. All the batteries connected should be of the same voltage and capacity rating to avoid charging problems and short battery life.

- In parallel connection batteries are connected by using a set of cables to connect both the positive terminals and another set of cables to connect both the negative terminals of both batteries to each other. In short, negative terminal to negative terminal and positive terminal to positive terminal. The load is then connected to one of the batteries. The current rating of the batteries when connected in parallel will increase but the voltage will be the same; heavier cables are needed to avoid burning cables due to increased amperage.
- In series/parallel Connection two sets of batteries which have been connected already in parallel can be joined together to form a series. Electricity flows in a single battery just the same as it flows through a parallel connection, therefore two batteries connected in parallel can also be connected in series. A cable is used to create a bridge between the positive terminals of a parallel bank to the negative terminal of another parallel bank.

#### **2.4.10 Voltage Filters**

Filters are used to block some frequencies while allowing other frequencies to go through. There are several different types of filter depending on the application.

The types of filters includes

- Low pass filter- is a filter that passes signals with a lower frequency than a certain cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency.
- Band pass filter- is a device that passes frequencies within a certain range and rejects frequencies outside that range.
- High pass filter- is an electronic device that passes signals with a frequency higher than a specific cutoff frequency and rejects signals with frequencies lower than the cutoff frequency.
- Notch filter- a band –stop filter with a narrow stop band.

### **2.4.11 The Charger**

The charger is a fixture which receives power from the bus bar and feeds it into the car battery. It is normally connected to an electrical outlet. The charger comprises a charging cable attached with a connector that can be coupled to a socket on the EV. The EV is connected to the grid for charging through the couple which consists of the connector and the socket. The plug of the charger looks similarly to that of fuel-pump nozzle and is used in the same way. The indication light shows if the EV is properly connected and charging is taking place, other stations has a button to initiate charging or stopping the process.

Some stations have auxiliary electronic features incorporated for smooth operation namely;

- Energy meter- is a device used to measure accurately and quickly electric vehicles charging amounts.
- Electronic payment system- is a system that enables users of EVCSs to pay electronically but not with physical cash.
- Internet access- the charging stations are connected to internet for easy access.
- Card controlled access system- allows for selective restriction of access in- to the charging network.

### **3 COUNTRY ANALYSIS AND THEIR EVCS SUPPLIERS**

Electric cars sales over the years have increased significantly as evident by the number of EVs on road. By the end of December 2014, approximately 712000 electric passenger cars and utility vans have been sold across the world. The countries with the highest sales are the USA with over 41% of the global sales, since 2008 followed by Japan of about 15% of the total sales and China with around 12% of the total global sale.

There are also some smaller countries which have made some remarkable improvement in the electric car sale race and its associate infrastructure development over the past few years. The country with the highest market penetration per capita in the world is Norway, also with the largest segment of the market share of new car sale for plug-in electric cars. The second largest EV market penetration per capita after Norway is Estonia, which is also the first country that completed a nationwide EV charging network coverage.

There are a number of EVCS suppliers or manufacturers across the globe with high tech equipment ranging from AC slow charging to DC fast charging. These includes e.g. Andromeda power, Evtronic, Bosch Automotive Service Solution Inc, Eaton, Efacec, ABB, Aerovironment, Fuji Electric, Schneider Electric, Delta Electronics, and Valent Power and Signet System.

Some selected countries are considered based on their strife and polices for the promotion of EVs and the subsequent EVCSs. These countries include Germany, France, Estonia, Switzerland, the UK, China, Israel and the USA.

#### **3.1 Analysis of EVCS Infrastructure in Germany**

Germany, the leading economy in Europe has by the end of December 2014 installed approximately 4800 Level 2 and 100 fast public charging stations. The four major transmission system operators in Germany are the 50hertz, Eon, Rwe and

EnBW. These operators are also the operators of electric vehicle networks to sell electricity power to EV owners in partnership with German car manufacturers.

Daimler AG, a car manufacturer is running a joint electrical car charging station project with the utility RWE AG in Berlin, the capital of German, known as the “E- Mobility Berlin.” They have been able to provide about 500 charging stations across Germany. The car manufacturer BMW also runs a joint electric car charging station project with the utility Vattenfall called “MINI E” in Berlin. The project has been able to erect 42 EVCS in Berlin and 50 EVCS in Hamburg. VW and E. ON also run a project in Berlin and in Wolfsburg. “The Electric Mobility Fleet Test”. E. ON has announced to provide the 200 EVCS in the Munich region. The carmaker Daimler, EnBW utility and the Baden-Wurttemberg government are in joint venture to provide about 700 charging stations in the Baden-Wurttemberg state, 13 EVCS in Stuttgart.

The government aimed in supporting a fleet of 1 million electric cars in Germany by 2020. An interim report published by the NPE indicates a test fleet of 2800 electric vehicles and 2500 EVCS in 8 regions. The Government statistics show a consumer study indicating that some 64 percent of Germans wish to buy an electric car, 51 percent expects a car to be charged in less than 2 hours, and 60 percent of consumers are comfortable with 4 hour charge. About 64 percent of electric car owners would like to charge in their own garage, 21 percent would prefer a public or central charging station and 6 and 4 percent opt for charging in parking lots of shops and companies. See Table 1 for the list of EVCSs in Germany.

Table1. List of EVCSs in the Germany.

<b>Status</b>	<b>Provider</b>	<b>Region</b>	<b>Number</b>	<b>Started</b>
Functional	Park&charge	Germany	115	1998
Functional	Drehstromnetz	Germany	190	2006
Functional	Vattenfall	Berlin	42	2009
Functional	RWE	Berlin	77	2009
Functional	Iadenetz.de	Germany	150	2010
Functional	RWE	Rhein-Ruhr	165	2010
Functional	RWE	Koeln-Bonn	57	2010
Functional	RWE	Rhein-Main	34	2010
Functional	RWE / Orlen	Hamburg	28	2010
Functional	RWE	Other	98	2010
Functional	E.ON	Munich	21	2009
Functional	EnBW	Stuttgart	25	2010
Functional	EnBW	Stuttgart/Karlsruhe	42	2011
Functional	E.ON	Bavaria/Saxonia	8	2014
Under Construction	Iadennetz.de	Germany	100	2012

Under construction	Con-	EnBW	Stuttgart/Karlsruhe	260	2011
Under construction	Con-	E.ON	Munich	200	
Under construction	con-	Vattenfall	Hamburg	50	2011
Under construction	Con-	RWE	Berlin	500	2011
Under construction	Con-	RWE	Rhein-Ruhr	400	2011
Planned		EnBW	Baden-Wutberg	700	2012

### 3.2 Analysis of EVCS Infrastructure in Estonia

Estonia is the first country in the world to complete a nationwide EVCS network which is more dominated by DC chargers than any other in Europe; it is the only country with such coverage. The Government of Estonia in partnership with Mitsubishi Corporation and ABB launched the nationwide EVCS network project. The network was officially opened with 165 fast chargers installed in urban residence amounting to about 5000 dwellers. Additional CHAdeMO-type DC fast chargers needing between 15 and 30 minutes to fully charge a car battery were installed on all highways at 60 km intervals. See Table 2 for the list of EVCSs in Estonia.



Table 2. List of EVCSs in Estonia.

<b>Region</b>	<b>Status</b>	<b>Provider</b>	<b>Number</b>	<b>Started</b>
Nationwide	Functional	G4S	700	2012

### 3.3 Analysis of EVCS Infrastructure in France

The carmaker Toyota in corporation with Electricite de France (EDF) is installing recharging points for EVs on roads, streets and parking lots. A major project is also underway for Renault- Nissan Alliance and Electric de France to promote a countrywide battery charging station network. The French Environment Ministry intends to install about 400000 charging points by the end of 2015. Also pilot projects are underway in cities like Paris, Strasbourg, Stuttgart and Yvelines. The government of Monaco also has drafted plans and policies to run fleet test including 300 charging stations and three fast charge stations. See Table 3 for the list of EVCSs in France.

Table 3. List of EVCSs in France.

<b>Status</b>	<b>Provider</b>	<b>Region</b>	<b>Number</b>	<b>Started</b>
Functional	Paris	Paris	101	2010
Functional	France	Strasbourg	135	2010
Under Construction	France	Ile de France	300	2011
Under Construction	Vinci Auto-Route	Western France	738	2012
Under Construction	France	Paris-Yvelines	200	
Proposed	France	Monaco	300	2011
Proposed	France	France	400,000	2010

### **3.4 Analysis of EVCS Infrastructure in the UK**

A UK based company Electromotive, Ltd in collaboration with Electrite de France a French based electric company, are strong stakeholders in the EVCS infrastructure in the UK. About 4000 charging points have been installed throughout the UK region, 400 public access charge points to charge your car project and 120 charging points across Scotland. An MOU has been signed between the UK base Elektromotive Ltd, a provider of ECCS and the Renault – Nissan Alliance to collaborate for ZE Mobility to increase the rate of installing EVCS in the cities of the UK. Special tax exemptions are arranged for purchasers of EVs and are free from annual vehicle tax of 155 pounds and an annual 1700 pounds congestion charges. London, the North East region and Milton Keynes have been earmarked for initial site location for EVCS.

The E- revolution project launched by the Mayor of London will see the construction of 25000 charging points including 500 on-street, 2000 off-street that on car parks and 22000 private stations. The Transport for London and the Siemens international also installed about 180 charging stations in the London region. See Table 4 for the list of EVCSs in the UK.

Table 4. List of EVCSs in the UK.

<b>Status</b>	<b>Region</b>	<b>Provider</b>	<b>Number</b>	<b>started</b>
Function	England North East	Elektromotive	400	2010
Function	England other	Elektromotive	287	2007
Function	Scotland	Elektromotive	120	2010
Function	England	Zero Carbon World	166	2010
Function	London	Siemens	1300	2011
Functional	UK	Ecotricity	397	2011
Under construction	Scotland	Funding program	44	2012
Planned	London, North-East		2500	2012
Planned	London		2500	2015
Planned	Central Scotland, EastEngland.Greater Manchester.Milton Keynes, North England.Ireland.		8500	2015
Planned	UK	Zero Carbon	1000	2012

### 3.5 Analysis of EVCS Infrastructure in Switzerland

Switzerland charging network is mainly derived from research work in solar cars. The Park and Charge network was started in 2010 in Switzerland and spread to other countries. See Table 5 for the list of EVCSs in Switzerland.

Table 5. The list of EVCSs in Switzerland.

Region	Status	Provider	Number	Started
Switzerland	Functional	Park&charge	230	1992

### 3.6 Analysis of EVCS Infrastructure in Israel

A favorable policy in Israel for zero- emissions vehicles was launched against their traditional counterparts to accelerate the changeover to electric cars. A collaboration between Better Place and the French car making firm, Renault initiated the construction of first electric vehicle network in Israel and opened its first functional charging station at Cinema City in Pi-Glilot with subsequent ones to be opened around Tel Aviv, Haifa, Kfar Saba, Holon, and Jerusalem. Better Place later filed for bankruptcy and terminated its projects in most markets. See Table 6 for the list of EVCS in Israel.

Table 6. List of EVCSs in the Israel.

<b>Status</b>	<b>Region</b>	<b>Provider</b>	<b>Number</b>	<b>Started</b>
Functional	Tel Aviv	Better Place	1	2010
Functional	Israel	Gnergy	4	2011
Under construction	Israel	Better Place	200	2011
Under construction	Israel	Gnergy	25	2011
Planned	Israel	Better Place	400	2011
Planned	Israel	Gnergy	500	2012
Proposed	Israel	Better Place.	220	2011

### 3.7 Analysis of EVCS Infrastructure in China

China opened the Tangshan Nanhu EVCS on March 31, 2010 which is the first largest EVCS to be opened in China. Other EVCS are been planned to be erected around Zhangjiakou, Quihuangdao, Langfang and the Chengde provinces. The Chinese State Grid Corporation is responsible for major EVCS infrastructure and battery replacement facilities across the country. The principal aim of the CGC is to install 10 million electric vehicles charging stations by 2020 to get rid of crude oil importation. See Table 7 for the list of EVCSs in China.

Table 7. List of EVCSs in the People's Republic of China.

Status	Region	Provider	Number	Date
Function	BeijingOutskirts	North China Grid	100	2010
Under construction	27 cities	State Grid Corp.		2010
Under construction	Zhejiang	State Grid Corp	7200	2011
Planned	China	State Grid Corp	6209	2010
Proposed	China	State Grid Corp	220000	2015

### 3.8 Analysis of EVCS Infrastructure in the USA

Coulomb Technologies has installed infrastructure in most states including the Arizona, New York, Massachusetts, Chicago, Florida, Washington D.C, California, San Francisco, San Jose, Walnut Creek, Minnesota, Cary, Ohio, Oregon, Portland, Michigan, North Carolina, Nashville, Tennessee, Texas, Seattle, Detroit, Minneapolis, Illinois and Wisconsin. The company planned to provide 1000 free public EVCS and also expand the ChargePoint America network to 4600 free home and public CS in nine regions.

The ChargePoint program sponsored by the American Recovery and Reinvestment Act has opened 149 stations of which 51 are in California and later 100 stations in New York which joined the program later. In 2012, the ChargePoint program partnered with Coulomb Technologies to install 2400 public and commercial charging stations in 10 regions. Other infrastructure has been planned by Better Place for states like, Hawaii, Oregon, and California. SolarCity and ECOtality

are other companies building EVCS throughout the states. Another project, The EV Project of ECOtality erected 1500 public charging stations across 11 cities including Texas and San Diego for 36 months. Also the Portland General Electric has installed 20 charging stations in a demonstration project for plug-in cars. The NRG Energy built 200 fast-charging stations in California over four years period. There are park and ride lots in the King county, including Seattle. Most charging sites in the Seattle area are free others charge around 7 dollars an hour. About 246 chargers have been funded by the DBEDT Ministry of Hawaii which has funded approximately 246 chargers and installed 220 charging stations. The EV Public Charging Station of Hawaii amount to 200 in 80 locations of which about 140 have been installed by BetterPlace. The Tesla car making company has installed about 18 public charging stations in California. Likewise, the General Motors EV1 charging station network program has installed 500 public charging stations in California. There are approximately 7904 public charging stations in the US as of 2014. See Table 8 for the list of EVCSs in the USA.



Table 8. List of EVCSs in the USA

<b>Status</b>	<b>Region</b>	<b>Provider</b>	<b>Number</b>	<b>Started</b>
Functional	US		7902	1992
Functional	Portland	Portland G. Electric	20	2008
Functional	California	Tesla	15	2010
Functional	California, Seattle, Texas, Florida, Georgia, Hawaii	Sema Connect		2010
Functional	California	ChargePoint	580	2010
Functional	Washington State	ChargePoint	237	2011
Functional	Chicago Area	JNS Power	350	2011
Functional	Boston	ChargePoint	108	2011
Functional	New York/ New Jersey	ChargePoint	128	2011
Functional	Washington DC / Baltimore	ChargePoint	164	2011
Functional	Florida	ChargePoint	275	2011
Functional	San Antonio / Houston	ChargePoint	261	2011
Functional	San Diego	EV Project	261	2012
Functional	Seattle	EV Project	407	2012

Functional	Houston	EV Project	177	2012
Functional	Tennessee	EV Project	365	2012
Functional	South Carolina	EATON	100	2010
Functional	Dallas / Houston	NRG Energy	15	2010
Functional	Hawaii	Better Place	140/200	2011
Under Construction	SF Bay Area		109	2010
Under Construction	San Diego	EV Project	1500	2012
Under Construction	Texas	NRG Energy	50	2010
Under Construction	California	NRG Energy	200	2012
Under Construction	Detroit, New York, Wash. DC, California, Washington, Austin	ChargePoint	4600	2011
Planned	San Diego, Arizona, Seattle, Oregon, Tennessee, Dallas.	EV Project	6350	2012

## **4 POLICIES OF SELECTED COUNTRIES ON EV AND THEIR INFRASTRUCTURE**

The principal advantage of CO<sub>2</sub> emissions from EVs and minimizing the dependence on oil fuel in the road transportation has led many countries to set targets for EV research and development over the last few years and have drafted a number of policies to attain environmental objectives. A number of governments are drafting more policies, such as financial incentives, technology support or charging infrastructure to boost the sale of EVs. This chapter reviews the relevant policies that the selected countries have adopted to stimulate the acceptance and the sale of EVs.

### **4.1 The Analysis of German EVCS Policy**

The Federal Government of Germany is pursuing a sustainable transport policy. Four main ministries in Germany, Economics and Technology, Transport, Building and Urban Development, Environment, Nature Conservation and Nuclear Safety, and Educational and Research have supported numerous projects including the E- Mobility project in the capital Berlin. The transport system should be made environment and climate friendly, social responsible and economically efficient.

#### **4.1.1 Policy Measures Supporting EVs**

The Government of Germany is pursuing the agenda of 1 million EVs in Germany by 2020 and has therefore drafted policies that will augment the sale and adoption of EVs in the country. Below are some enacted EV policies in Germany.

#### **Financial Support at Purchase and Usage:**

EV owners in Germany benefit from a couple of financial supports from the Government of Germany. Some of the incentives EV owners benefit from are listed below.

- Co-funding for purchase by authorities
- Yearly tax exemption / reduction for ten years.
- Co-funding operational costs by authorities
- Reduced electricity costs
- Company car taxation (in preparation).

### **Non-Financial Policy Measures Support for EVs:**

Apart from the financial support being enjoyed by the EV owners in Germany, there also non-financial benefits which are listed below.

- Support in standardization measures
- Transferrable license plates

#### **4.1.2 Policy Measures Supporting EVCS Infrastructures**

The German Government has EV target and therefore doing everything possible to attain that target. The infrastructure policy for EVCS drafted is mentioned below.

- Development of a uniform platform for information and data.
- Conceptualized city map for expanding the public charging structure.
- Participation in the future demonstration projects with the state funds.
- Designation of laboratory areas.

### **4.2 The Analysis of Estonia EVCS Policy**

Estonia, a leading country in the quest for nationwide EV charging network, has good policies regarding both EVs and their charging infrastructure. The policies support EV owners and it also encourages more adoption of EVs. Both financial and technical supports are entailed in their policies. The owners of EV enjoy benefits of tax incentives which are not enjoyed by their counter-

part ICE owners. Below are some of the enacted EV and their charging infrastructure policies of Estonia.

#### **4.2.1 Policy Measures Supporting EVs**

Estonia has both financial and no-financial support for the EV owners in the country. The policies are mentioned below.

##### **Financial Support at Purchase and Usage:**

EVs owners in Estonia are privileged to benefit from the following financial support during purchase:

- Purchase tax exemption / reduction
- Co-funding for purchase by authorities

##### **Non-Financial Policy Measures:**

Apart from the financial benefits EVs in Estonia enjoys, there are couples of other non-financial incentives which are listed below:

- Free Parking
- Supporting consultancy, education and promotion of EV use.

#### **4.2.2 Policy Measures Supporting EVCS Infrastructures**

Estonia is the only country with nationwide EVCS coverage. The users of EVs enter into agreement with ELMO- the network operator and pay as low as 30 Euros per month. The Government of Estonia procures full infrastructure solution at once by selling their CO<sub>2</sub> quota to Mitsubishi Corp.

1. Assets : Chargers and operating system
2. Services for 5 years: Maintenance, business, customer support.
3. Single Operator system.
4. Easier plan and execution of project.

### **4.3 The Analysis of French EVCS Policy**

The majority of policies, laws and legislations regarding electric vehicles in France relates to tax incentives, and building charging infrastructure. The Grenelle II legislation adopted in July 2010 highlighted a number of environmental topics, including EV charging.

#### **4.3.1 Policy Measures Supporting EVs**

The main and key policy support for EVs in France is general incentive provided to all zero or low CO<sub>2</sub> emission cars and not specifically for only EVs. Tax deduction for cars with low CO<sub>2</sub> emissions which automatically includes all electric cars.

#### **4.3.2 Policy Measures Supporting EVCS Infrastructures**

A charging infrastructure working group formed by the government to manage the installation of a standardized national charging network drafted the following provisions:

- Local governments are empowered to install public charging infrastructure.
- A quota of parking areas in work places and shopping areas are reserved for electric vehicles and charging spots
- Builders of collective residences must install charging facilities at park places upon request of the inhabitants
- Local governments will be obligated to equip public-parking areas with charging facilities.

### **4.4 The Analysis of Swiss EVCS Policy**

The Government of Switzerland is reluctant in promoting actively EVs with their associate charging infrastructure due to their earlier but unsuccessful attempt into

electrification of vehicles in the 1990s. They rather focus on developing the framework conditions for electric vehicles and public charging infrastructure to prevent preferential treatment for a particular technology. The only incentive benefitting EV owners is low CO<sub>2</sub> emission exemption tax which other new cars enjoy, as well. The government therefore believes that the introduction of EV should be driven by market forces.

#### **4.4.1 Policy Measures Supporting EVs**

There is no direct policy(s) supporting EVs in Switzerland due to the Swiss Government position on the matter.

#### **4.4.2 Policy Measures Supporting EVCS Infrastructures**

Utility operators in Switzerland have taken over the role of promoting EV since the government does not see it fit to facilitate and promote the EV and the charging infrastructure. The EV club Switzerland, a private association of EV users has been the pivotal promoting agent of EVCS infrastructure in Switzerland. An EV user has access to the Park&charge charging station if a payment of annual contribution is made.

### **4.5 The Analysis of UK EVCS Policy**

The Government of the UK is committed to decarbonize the road transport sector by promoting ultra-low emission vehicles. A subsidy program for car consumers called the Plug-in car grant encourages the purchase of ultra-low carbon vehicles. An initiative called the Plugged-In Places (PIP) has created a hub for EVs by installing charging points in six regions throughout the UK. The UK's committee for climate change also submitted that a few hundred million pounds could be needed to establish charging infrastructure to support 1.7 million EVs\_ although the UK has not stated EV target yet.

#### **4.5.1 Policy Measures Supporting EVs.**

The UK Department for Transport (DfT) outlined the UK Government's five structural reforms transport priorities which include a commitment to tackle CO<sub>2</sub> and road congestion. The DfT therefore states to support early market for electric vehicle and other low emission vehicles by specifying the following actions:

- Consolidate existing support mechanism for low and ultra-low emission vehicle research and development.
- Promote consumer uptake of ultra-low emissions vehicles.

Other benefitting policies are:

- Plug-in car grant
- Vehicle Exercise Duty Exempt
- Company Car Tax — Employees and employer exempt from income and national insurance contribution.
- Van Benefit charge — Employees and employers exempt from income and national insurance contribution.
- Fuel Benefit Charge Exempt
- 100% first-year allowance
- 100% discount on London congestion charge
- Exemption or reduced parking charges for electric vehicles

#### **4.5.2 Policy Measures Supporting EVCS Infrastructures**

The policy measures supporting the investment and construction of EVCS in the UK are listed below.

- GBP 37 million for thousands of charging points for residential, streets, railways, and public sector locations is available
- Push for early European Union (EU) adoption of electric vehicle infrastructure standards



- Developing a nationwide strategy to promote the installation of EV infrastructure
- Support the Plugged-In places pilots program to encourage the establishment of electric vehicle recharging infrastructure across the UK and inform the development of the electric vehicle infrastructure strategy

## 4.6 The Analysis of Chinese EVCS Policy

China is the largest emitter of CO<sub>2</sub> in the world and has recently striven to develop EV and holds the largest market share of EVs in the world. The Government of China provides some incentives to EV owners to stimulate the EV market. The policy of EV in China is divided in two; incentive and technical support. The Government of China is determining to promote the sale of EVs thereby reducing their emission of CO<sub>2</sub>.

### 4.6.1 Policy Measures Supporting EVs

**Public and Private Procurement:** The incentive support is divided into two main parts, namely government purchase and private purchase. Originally, the EV promotional sale follows the policy of government purchase where government institutions and agencies purchase large number of EV vehicles for official purposes. Private purchase is when private owners are given tax exemptions. Other incentives for private purchase include subsidies, no license plate and no traffic controls; these have also been proposed to attract more private customers.

**Subsidies for purchasing EV:** Chinese government provides national subsidy of 50,000 Yuan and 35000 Yuan per vehicle for plug-in hybrid electric vehicles with range over 150km and 80km respectively and 60,000 Yuan per vehicle for pure electric Vehicles with a range over 250km. Buses also receive subsidies, depending on the length of the bus; for buses over 50m in length, EVs receive 500,000 Yuan, and PHEVs receive 250,000 Yuan. 8m and 6m length buses receive 400,000 Yuan and 300,000 Yuan respectively. /23/

**Tax reduction for purchasing EVs:** EVs will be exempted from tax on vehicles and vessels. From September 1, 2014 to the end of 2017, the government will waive the auto-purchase tax (up to 10%) for all EVs.

#### **4.6.2 Policy Measures Supporting EVCS Infrastructures**

The EV infrastructure of the People Republic of China is mainly constructed and supervised by the State Grid Corporation of China (SGCC) or the China Southern Power Grid (CSPG). The city of Shanghai in China will maintain a ratio of 1.2-1.5 charging stations for every electric vehicle. Cities that register more EVs are to be rewarded by the government for operation and upgrade of charging infrastructure and construction of charging/battery swap stations. /23/

#### **4.7 The Analysis of American EVCS Policy**

The American Recovery and Reinvestment Act of 2009 authorized federal tax credits for qualified PEVs, and the credits range from \$2500 to \$5000, depending on the capacity of battery. Some states have established incentives, including fiscal and non-fiscal incentives. The fiscal incentives include tax reduction or exemptions and rebates for both BEVs and PHEVs, and the non-fiscal incentives include free access to high occupancy vehicle lanes. The Government of the United States has also encouraged manufacturers of EV to promote the development of EVs by proposing some policies on tax reduction, low loan interest and research and development (R&D) investment./14/

##### **4.7.1 Policy Measures Supporting EVs**

The policy measures supporting EVs in the United States are as follows;

- The Federal Government of America currently offers a tax credit of up to \$ 7500 for PEV purchases.
- The state offers a vehicle purchase rebate of up to \$ 2500

- Zero – Emission vehicles allowed in HOV lanes regardless of number of passengers.
- Electrification of 20 percent of vehicle fleet by 2030.
- Electric vehicles are exempt from vehicle emissions inspection requirements.
- Barriers to PEV adoption have been reduced by addressing building codes, electrical codes, and fees for charging. /6/

#### **4.7.2 Policy Measures Supporting EVCS Infrastructures**

The policy measures supporting EVCS in the United States are listed below;

- The American Recovery and Reinvestment Act and clean Fuel Alternative Transportation have been able to sponsor a number of EVCSs projects across the nation.
- The permitting and inspections process for EVSE (EVCS) is streamlined.
- In Oregon, up to \$ 750 is offered by the state for residential charging installations and up to 35 percent tax credit for businesses installing charging stations. /6/

## **5 ELECTRICITY GENERATION OF THE SELECTED COUNTRIES**

### **5.1 Electricity Generation in Germany**

Germany's main source of electricity is predominantly fossil fuels. There were plans to build new coal power plants which are now controversial due to Germany's commitment to reduce emission; this plan have been curtailed by the Germans government's CO<sub>2</sub> reduction targets and the growing shares of renewable energy in the national electricity market. Coal made up about 45% of Germany's electricity production in 2013 (19% from hard coal and 26% from lignite). Coal-fired plants are been modernized to be flexible to support renewable energies technologies. The coal consumption in Germany dropped first time in 2014 since the 2009 recession. Lignite is mined in the western and the eastern parts of the country; significant amount of this coal are burnt in the coal firing plants which are sited near the mining areas to production electricity than transporting over long distances which is not economically feasible.

In 2014, electricity production by nuclear power dropped to 16% as compare to 23% in 2010. This scenario has resulted in the rise of coal consumption during the last few years. A coalition government took decision in 2002 to phase out all nuclear technologies in 2022; Siemens, Germany's engineering giant, announced a complete withdrawal from the nuclear industry

Renewable energy shares of electricity in the Germans market have increased drastically over the last few years due to huge investment in renewable technologies. During the beginning of 2012, 25.1% of the Germany's electricity supply was generated from renewable sources, more than nuclear technology electricity. The installed capacity of renewable energy by the end of 2011 was 65.7GW.

Table 9. Primary sources of electricity in Germany by percentage./17/

Hard coal	17.8
Lignite	25.4
Natural gas	9.5
Nuclear	15.8
Renewables	26.2
Mineral oil	1.0
Others	4.3

## 5.2 Electricity Generation in Estonia

Electricity is mainly generated in Estonia by the use of oil shale. The Narva power plants in Estonia provide about 90% of the electricity produced in Estonia; remaining power is produced from biomass and wind. Owned by Eesti Energia, the power plants are the world's largest power stations running on oil shale. The power plants produce about 10 TWh of electricity each year. A new power plant under construction using the latest technology will replace half of the oil shale with sustainable biomass.

Table 10 Primary sources of electricity in Estonia by percentage./17/

Oil Shale	90
Other	10

### 5.3 Electricity Generation in France

The dominant source of electricity production in France is nuclear power, amounting to 77% of the overall electricity produced in France by the end of 2012, followed by renewable and fossil fuels amounting to 15% and 8% respectively. This is the largest share of nuclear power in the world, and France is also one of the world's net exporter of electricity. The French Government owned almost the entire nuclear power sector.

Table 11. Primary sources of electricity in France by percentage./17/

Coal	4.08
Oil	0.58
Non-hydro	4.47
Natural gas	3.69
Nuclear	76.6
Hydro	10.2

### 5.4 Electricity Generation in Switzerland

Electricity generation in Switzerland mainly depends on hydroelectricity due to the presence of the Alps, which covers about two-third of the country's land mass. The Alps provide many mountain lakes suitable for hydro power. The net generation in 2013 amount to 66.2 terawatt-hours and relatively high consumption of about 22% above the Europe standard. About 60% of the country's electricity comes from sustainable sources, especially from hydro: other renewables sources amount to 3.4%, nuclear contributing nearly 37.6% and fossil fuels contributing only 2.5% to the national generation.

Table 12. Primary sources of electricity in Switzerland by percentage./17/

Hydro-ROR	26.8%
Hydro-dam	29.7%
Solar PV	0.8%
Biogas	0.4%
Wood	0.4%
Wind	0.1%
Waste Incin.-	1.6%
Nuclear	37.6%
Fossil fuel	2.5%

## 5.5 Electricity Generation in UK

Different means are used to generate electricity in the UK. The UK electricity mix comprises different sources ranging from fossil to renewable, likewise different technologies are employed to ensure constant supply of electricity year round without any interruption and to reduce over reliant on one particular type of power generation. /18/

Discussed below are the various kinds of energy sources the UK used for their electricity generation and the amount of electricity produced from each source.

### 5.5.1 Fossil Fuels

The main source of the UK electricity generation is fossil fuels mainly natural gas which accounts for 30.2% of the total electricity production in the second quarter

of 2015, coal accounted for 20.5%, oil and other source 2.5%. Electricity generation from these sources changes annually depending on fuel prices. /18/

### **5.5.2 Nuclear Power**

Nuclear power generation in the UK changes from year to year, it is reported that over the next few years, old nuclear power stations will be shut down gradually with new ones to replace them to boost up power generation from nuclear by 2025. Currently, the nuclear share of UK electricity is 21.5% which is expected to rise to 25% by 2025. /18/

### **5.5.3 Renewable Energy**

The renewable energy mix of the UK includes wind, wave, marine, hydro, biomass and solar. It adds up to 25.3% of electricity generated in the second quarter of 2015. The increase in renewable energy will continue as the UK determines to meet the EU targets of generating 30% of electricity from renewables.

### **5.5.4 Imported Power**

The net import of electricity the UK import from neighboring countries amount to 6.9% of the total generation

Table 13. Primary sources of electricity in UK by percentage./17/

Natural Gas	30.2
Coal	20.5
Nuclear	21.5
Renewable	25.3
Oil and other.	2.5



## 5.6 Electricity Generation in China

The Chinese electric power industry is the largest electric consumer in the world, surpassing the United States in 2011. It generated 5583TWh of electricity in 2014 that is 25% more power than the States was able to generate in 1996. The country has enormous energy reserves. China has the world's third-largest coal reserves and huge hydroelectric resources.

Coal is the main source in the Chinese electricity generation which accounts for 63% follow hydroelectric 22%, wind 6%, Natural gas 4%, nuclear 3% and finally solar 1%. These are 2015 projected figures. The Government of China plans to curb down the use of coal to 62% of total electricity generation by 2020 to reduce heavy air pollution in the country in recent years. The percentage of the non-fossil fuel is expected to rise to 15% by 2020 and 20% by 2030 to reduce the country's dependence on coal. /6/

Table 14. Primary sources of electricity in China by percentage. /17/

Coal	63
Hydropower	22
Wind	6
Natural Gas	4
Nuclear	1
Oil	2
Solar	1
Biomass and other.	1

## 5.7 Electricity Generation in Israel

Power generating companies in Israel use different kinds of primary energy sources for their power generation. In all, there are five coastal power stations operating on coal, heavy fuel and natural gas, also a number of other stations based on jet, combined cycle gas turbine and diesel powered plants. Most electricity in Israel comes from hydrocarbon fuels burnt in ICE power plants.

Renewable energy is produced from solar fields and from biogas, hydroelectricity and wind power. Less than 2% of the country's electricity is derived from renewable sources due to the recent discoveries of vast natural gas reserve in the Israeli territories; the Government of Israel's interest in renewable energies is dimmed but has promised to attain its 2020 goal of 10% electricity from renewable sources.

Table 15. Primary sources of electricity in Israel by percentage./17/

Coal	61
Fuel Oil	0.9
Natural Gas	36.6
Diesel	1.5

## 5.8 Electricity Generation in the USA

The second largest producer of electricity (after China) is the United States of America at the end of 2014. The majority of the US electricity is derived from the fossil fuel: statistics from 2014 show that 39% of the state's electricity comes from coal, 27% comes from natural gas, 19% from nuclear power, 6% from hydropower, 7% from other renewables. The United States produced about 4093 bil-

lion kilowatt-hours of electricity by the end of 2014 of which about 67% was from fossil fuels (coal, natural gas, and petroleum).

Table 16. Primary sources of electricity in the US by percentage./17/

Coal	39
Natural gas	27
Nuclear	19
Hydropower	6
Biomass	1.7
Geothermal	0.4
Solar	0.4
Wind	4.4
Petroleum	1
Other gases	1

## 6 SUMMARY AND CONCLUSION

This chapter deals with the summary of the theoretical objectives, analyzing the main findings, giving recommendations and contributions. The studies also present critical issues which needs sufficient investigation.

### 6.1 Theoretical Objectives of the Studies

The beginning of the research presents the general concept of EVCS detailing the various types of EVCSs, technical constructions, operation, various equipment and their functions. It is stated that for the benefit of concise and precision only public charging station would be studied. It was found that there are basically four ways of charging the electric vehicle which includes the following methods:

- Residential Charging (Level 1 Chargers)
- Charge while parked (Level 2 Chargers)
- Battery Swap
- Fast Charging at Public Charging Station (Level 3 Chargers).

The operation of the EVCS was found to be similar to that of fuel station but delivers different product in the form of electric power instead of liquid fuel. Electric power is delivered through the transformer to the charging stations by the grid. The constructions are also similar with the EVCS comprising of basically electrical equipment and apparatus, such as cables, wires, intelligence devices, electrical transformers, bus bars and more electronic frameworks while the gas fuel station is more of mechanical framework.

The selected countries were analyzed base on their advancement and development so far as EVCS are concerned. The selected eight (8) countries include; Germany, France, Estonia, Switzerland, UK, China, Israel and the USA. In Germany approximately 4800 level 2 public charging stations and 100 fast public charging stations are installed by the end of 2014. These charging stations are installed by car manufacturers in joint partnership with electric transmission system operators

in Germany. The next country is the Estonia which became the first country to complete a nationwide EVCS network comprising of 165 DC fast chargers covering the whole country installed by ABB in collaboration with Mitsubishi Corporation.

In collaboration with the giant car manufacturers Toyota, Electricite de France (EDF) installed recharging points for EVs. Approximately 236 charging points are functional, 1238 more under construction and the French Environment Ministry intends to install about 400000 charging points by the end of 2015. The UK based company Electromotive, Ltd in joint venture with Electricite de France to install EVCS throughout the UK region. Currently approximately 2670 EVCS are functioning, 6544 are under construction and 13500 are planned project. The Swiss network is only derived from solar car research work. There are about 230 functional charging stations provided by Park&charge.

Better Place and Renault initiated the construction of first electric vehicle network in Israel, five charging stations are functional in Israel with 225 more under construction, 900 in planning state and 220 been proposed. In China, the Chinese State Grid Corporation is responsible for major EVCS project across the country. The largest EVCS, Tangshan Nanhu was inaugurated by the Chinese people in 2010. The aim of CGC is to erect approximately 10 million EVCS by 2020 to curb down crude oil importation. About 100 stations are functional, 7200 under construction, 6209 in the planned state and 220,000 more proposed by the end of 2015. The USA EVCS projects are executed by a number of agencies or organizations namely; Coulomb Technologies, The American Recovery and Reinvestment Act, Better Place, ECOtality, Portland General Electric, NRG Energy, the DBEDT, Tesla and the General motors. There are approximately 7904 public charging stations in the US as of 2014.

Various policies of EV and EVCS of the selected countries are analyzed to determine the factors that drive the electric vehicle market; the policies are not compared since they all have quite similar features.

Germany policies on both EV and EVCS are intriguing the summaries are listed below.

Policies supporting EVs in Germany:

- Co-funding purchasing by the authorities.
- Yearly tax exemption / reduction for ten years
- Co-funding operational costs by authorities
- Reduced electricity costs
- Company car taxation exempted
- Support in standardization measures
- Transferrable license plates

Policies measures supporting EVCS Infrastructure

- Development of a uniform platform for information and data.
- Conceptualized city map for expanding the public charging structure
- Participation in the future demonstration projects with the state funds
- Designation of laboratory areas for EVCS

Estonia, a leading country in the EVCS network race, have really fascinating policies regarding their EV and EVCS, below are some of their policies.

Policies measures supporting EVs:

- Purchase tax exemption / reduction
- Co- funding for purchase by authorities
- Free parking
- Supporting consultancy, education and promotion of EV use.

Policies measures supporting EVCS Infrastructure

- Assets: chargers and operating system
- Services for 5 years: Maintenance, business, customer support
- Single operator system
- Easier plan and execution of project

In France, the main policy is regarding tax incentives.

Policies measures supporting EVs in France

- Tax deduction for cars with low CO<sub>2</sub> emissions which automatically includes electric vehicles.

Policies measures supporting EVCS Infrastructure in France

- Local governments are empowered to install public charging infrastructure
- A quota of parking areas in working places and shopping areas are reserved for electric vehicles and charging spots
- Builders of collective residences must install charging facilities at park places upon request of the inhabitants
- Local government will be obligated to equip public- parking areas with charging facilities.

In Switzerland, there are no special policies for EV and their EVCS due to earlier unsuccessful attempt in the 1990s. The only policy supporting the EVs is the low CO<sub>2</sub> exemption tax which basically is for all cars, not necessary electric cars. Utilities operators in Switzerland are fully responsible for promoting EV and EVCS infrastructure. A private association of EV users, EV club Switzerland, are in charge for manning and promoting EVCS in the Swiss.

The UK department for Transport (DfT) outlined five structural reforms to decarbonize their transportation system by supporting early market for electric vehicles and other low emission vehicles by taking the following actions.

- Consolidate existing support mechanism for low and ultra-low emission vehicle research and development.
- Promote consumer uptake of ultra-low emissions vehicles

- Plug-in car grant
- Vehicle Exercise Duty Exempt
- Company car tax – employees and employer exempt from income and national insurance contribution.
- Van Benefit
- Fuel Benefit Charge Exempt
- 100% first year allowance
- 100% discount on London congestion charge
- Exempt or reduced parking charges for electric vehicles

Policies measures support for EVCS Infrastructure of UK:

- GBP 37 million for thousands of charging points for residential, streets, railways, and public sector locations is available.
- Push for early European Union (EU) adoption of electric vehicle infrastructure standards.
- Developing a nationwide strategy to promote the installation of EV infrastructure.
- Support the plugged- in places pilots program to encourage the establishment of electric vehicle recharging infrastructure across the UK and inform the development of the electric vehicle infrastructure strategy.

The Chinese Government provides two kinds of incentive supports for EV users namely;

Government purchase is where government institutions and agencies purchase large number of EV vehicles for official purposes. The government provides national subsidy of 50000 RMB for plug-in hybrid electric vehicles and 60000 RMB for pure electric vehicles.

This is when private owners are given tax exemptions and other incentives such as; no license plate and no traffic control.



There seems to be no special policy for the EVCS in the China since most of the project is executed by governmental agency (SGCC) or the (CSPG).

The USA policy support mechanism for EVs and EVCS are summarized below:

Policies measures supporting EVs in America:

- The Federal Government of America currently offers a tax credit of up to \$ 7500 for PEV purchases.
- The state offers a vehicle purchase rebate of up to \$ 2500
- Zero – Emission vehicles allowed in HOV lanes regardless of number of passengers.
- Electrify 20 percent of vehicle fleet by 2030.
- Electric vehicles are exempted from vehicle emissions inspection requirements.
- Barriers to PEV adoption have been reduced by addressing building codes, electrical codes and fees for charging.

Policies measures supporting EVCS in America:

- The American Recovery and Reinvestment Act and clean Fuel Alternative Transportation sponsor a number of EVCSs projects across the nation
- The permitting and inspections process for EVSE (EVCS) is streamlined for easy acquisition
- In Oregon, up to \$ 750 is offered by the state for residential charging installations and up to 35 percent tax credits for businesses installing charging stations

The primary sources of electricity in the selected countries were analyzed. The main idea was to investigate the level of fossil sources used in these countries to ascertain the degree of CO<sub>2</sub> management between reductions in the road transportation system or transferred to the power plants. In Germany, about 53.7% of

their electricity is generated by fossil which primarily comprises of coal, natural gas and mineral oils. The rest comes from renewable, nuclear and other sources. Table 9 gives further details about the electricity generation trend of Germany.

In Estonia, about 90% of its electricity is generated from oil shale, the remaining is by biomass and wind. The figure then indicate the fossil and its consequent CO<sub>2</sub> level. France has a different story in terms of fossil fuel usage in their electricity production since nuclear power is a dominant element in their electricity industry. About 76.6% of their electricity comes from the nuclear power which is almost owned by the French government. In Switzerland, hydro power and nuclear power are more dominant with less fossil source while in the UK, natural gas and coal are the leading sources are being competed by renewable sources and nuclear power.

Having the third largest coal reserve in the world and with enormous hydroelectric resources, China's main source of electricity is the coal followed by hydropower. Close to 63% of the Chinese electricity is from coal; studies shows that the Chinese is the largest emitter of CO<sub>2</sub> in the world. Finally, both Israel and America also derive most of their electricity from coal and natural gas as shown in their respective tables.

## **6.2 Findings and Contribution**

The study has successfully gathered helpful information on the availability of Electric Vehicle charging facilities across the globe which is a means of yardstick to the acceptance of electric vehicles, thereby boosting the level sale of such vehicles in the global market. This research also presents the general picture of the transitional period from ICE vehicles to pure electric vehicles, the perceptions of certain governments based on their previous experiences, the electricity sources of these countries informing their decisions on EV. It was found that most of these countries, such as China and Germany have EVCS targets while Estonia has already completed a nationwide network been the first of its kind.

The second phase of the research presents the fact that event though most of these countries are working tirelessly to increase easy access to EVCS facility based on their outlined policies therefore ensuring less carbon transportation system, the question of CO<sub>2</sub> emission management is still an issue as most of these countries electricity (needed to charge the electric vehicles) production is fossil fuel based and not likely to be changed sooner or later. Almost all the analyzed countries rely on either coal or natural gas, with exception of Switzerland and France who rely mostly on hydropower and nuclear power respectively.

### **6.3 Suggestions for Further Research**

Apart from the fact that this research is an information gathering study, it also seeks to address the issue of global warming to a certain limit as carbon free transportation system is a partial solution for global warming. In this respect it is deemed fit to suggest the following topics relating to EVs and CO<sub>2</sub> and heat emission into the atmosphere.

- The amount of CO<sub>2</sub> and heat emission reduction since the inception of EVs into the market
- The number of EVs required on the road to reduce global emission of CO<sub>2</sub> and heat to a significant amount
- The rough time frame for global completion of EVCS network

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