Modern Electric Cars

Grigol Lazriev[1]

I. Introduction

The climate is changing. The earth is warming up, and there is now overwhelming scientific consensus that it is happening, and human-induced. Climate change presents a fundamental challenge to global sustainable development. Urgent action is required to establish progressive policy regimes and achieve substantial reductions in greenhouse gas (GHG) emissions. Delay in reducing GHG emissions significantly increases the rise of more severe climate change impacts.

According to the comprehensive study led by the Center for International Climate and Environmental Research in Oslo, 15% of the manmade carbon dioxide (CO_2) in the Earth's atmosphere comes from cars, trucks, airplanes, trains, and ships. The scientists reported that within the transport sector, road transportation (cars, buses and trucks) contribute the most GHGs.

Cumulative global CO_2 emissions between now and 2050 will strongly influence the extent of climate change by the end of this century. Transport emissions could become even more significant as other sectors are decarbonised. Electrification of road transport via hybrid and fully electric vehicles is expected to contribute significantly to GHG reduction.

Nissan has predicted that one in 10 cars globally will run on battery power alone by 2020 and by 2020 electric cars and other green cars will take a third of the total of global car sales.

Designing and using electric cars - decarburization of road transport is a key priority for many Governments. Government policies and regulations, driven by different factors such as stricter carbon emission standards to independence from foreign energy, will heavily influence the marketability of Electric cars and other technology innovations. Several countries are upping their game to manufacture alternative vehicles. With a view to facilitate the adoption of such vehicles, the motor industry will be keeping a close eye on the latest developments.

Worldwide, close to $44 billion in economic stimulus funds and other incentives are being directed towards the development of alternative fuel and advance technology vehicles. United States is leading in terms of economic stimulus and other government incentives with an estimate of US$27.4 billion directed towards alternative fuel technologies such as electric vehicles. Australia's Green Car Plan will invest AUD$1.3 billion towards innovation and design of more environmentally-friendly vehicles. In Germany, the government has set its sights to have one million Electric cars on the road by 2020. It is supporting this with a EUR 500 million investment towards development of batteries and analysis of how Electric cars can be introduced in certain regions of the country.

Decarbonized smart electric grids and electric charging infrastructure are critical to the realization of low-carbon transport goals.

Georgia is a very reach country in RE resources, especially in hydro. For the last years the energy policy of Georgia has been favorable to the climate change mitigation. The share of hydro power in total energy generation has increased from 72% in 2006 to 92% in 2010. Accordingly emissions of CO_2 have been reduced by 890 ktCO_2.

The overall goal of the Government of Georgia is to move to 100% hydro utilization and evolve into a major regional exporter of clean electricity. According to the experts judgments, by 2050 Georgia will be able to export more than 50 billion kWh “clean electricity” in neighboring countries and in European Union.

By the initiative of the President Georgian State fleet of cars will soon be filled with electric cars - this will significantly reduce use of fuel and accordingly will reduce air pollution and GHG emissions in Georgia. The President of Georgia Mikheil Saakashvili tested electric car - drove an electric car produced by Nissan himself on the highway in Cancun within the frames of UN Climate Change Conference (COP16).

Mr.G.Lazriev – Head of Department of Hydrometeorology and Climate Change, Ministry of Environment Protection of Georgia

II. Electric car

An electric car is an automobile which is propelled by electric motor, using electrical energy stored in batteries or another energy storage device. The energy crises of the 1970s and 80s brought a short lived interest in electric cars. In the mid 2000s a renewed interest in the production of electric cars took place mainly due to the need to curb the greenhouse gas (GHG) emissions. As of early 2011 series production models available in some countries include the Nissan Leaf, Ford Focus Electric, Tesla Roadster, REVAi, Mitsubishi i MiEV, Th!nk City, etc. An important goal for electric cars is overcoming the disparity between their costs of development, production, and operation, with respect to those of equivalent Internal Combustion Engine (ICE) cars.

Advantages and Disadvantages of Electric cars

Electric cars have several potential benefits as compared to ICE cars that include (1) a significant reduction of urban air pollution; (2) reduced GHG emissions depending on the fuel and technology used for electricity generation to charge the batteries; and (3) less dependence on foreign oil. High oil prices have an adverse impact on the country balance of payments, hindering the economic growth.

Another important advantage of battery-powered motors over gasoline or diesel powered engines is the lower cost of the fuel that is, electricity for electric cars and oil products (gasoline or diesel) for the ICE cars.

In addition, almost 100 percent of the batteries can be recycled, which keeps old batteries from becoming a disposal problem.

Despite their potential benefits, widespread adoption of electric cars faces several hurdles and limitations:

- Electric cars are significantly more expensive than conventional ICE cars due to the additional cost of their lithium-ion battery pack. However, battery prices are coming down with mass production and expected to drop further;
- Lack of public and private recharging infrastructure and the driver's fear of the batteries running out of energy before reaching their destination (range anxiety) due to the limited range of existing electric cars;
- A long time is required to recharge the batteries.

Price

Electric cars are generally more expensive than gasoline cars, mainly due to the high cost of car batteries. Car buyers seem to be unwilling to pay more for an electric car that prohibits the mass transition from ICE cars to electric cars.

Charging

Batteries in electric cars must be periodically recharged. Unlike vehicles powered by fossil fuels, electric cars are most commonly and conveniently charged from the power grid overnight at home, without the inconvenience of having to go to a filling station. Charging can also be done using a street or shop charging station.

Energy efficiency

Internal combustion engines are relatively inefficient as most of the energy is wasted as heat. On the other hand, electric motors are more efficient. Typically, conventional gasoline engines effectively use only 15% of the fuel energy content to move the vehicle or to power accessories, and diesel engines can reach on-board efficiencies of 20%, while electric drive vehicles have on-board efficiency of around 80%.

Production and conversion electric cars typically use 10 to 23 kWh/100 km. About 20% of this power consumption is due to inefficiencies in charging the batteries.

Table A: Energy efficiency of the currently available on the market electric cars and pre-production models

	Tesla Roadster	Ford Focus Electric	Nissan LEAF	Smart fortwo electric drive	Mitsubishi i MiEV	Citroën C1 ev'ie
Economy in urban, kWh/100km	17.4	20.7	21.25	12	18.7	14.4

Running costs and maintenance

An electric car has only around 5 moving parts in its motor, compared to a gasoline car that has hundreds of parts in its internal combustion engine. Most of the running cost of an electric car can be attributed to the maintenance and replacement of the battery pack. Electric cars have expensive batteries that must be replaced but otherwise incur very low maintenance costs, particularly in the case of current Lithium based designs.

Nissan estimates that the Leaf's 5 year operating cost will be 1,800$ versus 6,000$ for a gasoline car.

Safety

The safety issues of Electric cars are largely dealt with by the international standard ISO 6469. This document is dealing with specific issues:

- On-board electrical energy storage, i.e. the battery
- Functional safety means and protection against failures
- Protection of persons against electrical hazards.

Firefighters and rescue personnel receive special training to deal with the higher voltages and chemicals encountered in electric and hybrid electric vehicle accidents. While BEV accidents may present unusual problems, such as fires and fumes resulting from rapid battery discharge, there is apparently no available information regarding whether they are inherently more or less dangerous than gasoline or diesel internal combustion vehicles which carry flammable fuels.

Great effort is taken to keep the mass of an electric vehicle as low as possible to improve its range and endurance. However, the weight and bulk of the batteries themselves usually makes an EV heavier than a comparable gasoline vehicle, reducing range and leading to longer braking distances; it also has less interior space. However, in a collision, the occupants of a heavy vehicle will, on average, suffer fewer and less serious injuries than the occupants of a lighter vehicle; therefore, the additional weight brings safety benefits despite having a negative effect on the car's performance. An accident in a 900 kg vehicle will on average cause about 50% more injuries to its occupants than a 1,400 kg vehicle.

Range and re-fuelling time

Cars with IECs can be considered to have indefinite range, as they can be re-fuelled very quickly almost anywhere. Electric cars have less maximum range on one charge than cars powered by fossil fuels, and they can take considerable time to recharge. This is a reason that many automakers marketed Electric cars as "daily drivers" suitable for city trips and other short hauls.

One way automakers can extend the short range of electric vehicles is the installation of DC Fast Charging stations with high-speed charging capability. From three-phase industrial outlets the consumers could recharge the 160 km battery of their electric vehicle to 80 percent in about 30 minutes. A nationwide fast charging infrastructure is currently being deployed in the US that by 2013 will cover the entire nation. Nissan has announced that 200 of its dealers in Japan will install fast chargers for the December 2010 launch of its Leaf EV, with the goal of having fast chargers everywhere in Japan within a 40 km radius.

Another way is building Electric cars with battery switch technology. An EV with battery switch technology and a 160 km driving range will be able to go to a battery switch station and switch a depleted battery with a fully charged one in 1 minute giving the EV an additional 160 km driving range. The process is cleaner and faster than filling a tank with gasoline and the driver remains in the car the entire time, but because of the high investment cost, its economics are unclear.

Air pollution and carbon emissions

Electric cars contribute to cleaner air in cities because they produce no harmful, such as particulates (soot), volatile organic compounds, hydrocarbons, carbon monoxide, ozone, lead, and various oxides of nitrogen. The clean air benefit is usually local because, depending on the source of the electricity used to recharge the batteries, air pollutant emissions are shifted to the location of the generation plants. The amount of carbon dioxide emitted depends on the emission intensity of the power source used to charge the vehicle, the efficiency of the said vehicle and the energy wasted in the charging process.

An EV recharged from the existing US grid electricity emits about 115 grams of CO_2 per km driven, whereas a conventional US-market gasoline powered car emits 250 gCO_2/km.

In France, which has a clean energy grid, CO_2 emissions from electric car use would be about 12g per kilometer.

Hazard to pedestrians

At low speeds, electric cars produced less roadway noise as compared to ICE cars. Blind people or the visually impaired consider the noise of combustion engines a helpful aid while crossing streets, hence electric cars and hybrids could pose an unexpected hazard. Tests have shown that this is a valid concern, as vehicles operating in electric mode can be particularly hard to hear below 30 km/h for all types of road users and not only the visually impaired. At higher speeds the sound created by tire friction and the air displaced by the vehicle start to make sufficient audible noise.

Cabin heating and cooling

Electric vehicles generate very little waste heat and resistance electric heat may have to be used to heat the interior of the vehicle.

Higher efficiency and integral cooling can be obtained with a reversible heat pump, which is currently implemented in the hybrid cars.

Batteries

Most current highway-speed electric car designs focus on lithium-ion and other lithium-based variants. Lithium based batteries are often chosen for their high power and energy density but have a limited shelf-life and cycle lifetime which can significantly increase the running costs of the vehicle. Variants such as Lithium iron phosphate and Lithium titanate attempt to solve the durability issues with traditional lithium-ion batteries.

Travel range before recharging

The range of an electric car depends on the number and type of batteries used. One way automakers can extend the short range of electric vehicles is the installation of Fast Charging stations with high-speed charging capability.

An alternative to quick recharging is to exchange the drained or nearly drained batteries (or battery range extender modules) with fully charged batteries. Batteries could be leased or rented instead of bought, and then maintenance deferred to the leasing or rental company, and ensures availability.

Renault announced at the 2009 Frankfurt Motor Show that they have sponsored a network of charging stations and plug-in plug-out battery swap stations. Other vehicle manufacturers and companies are also investigating the possibility. Replaceable batteries were used in the electric buses at the 2008 Summer Olympics.

Lifespan

Battery life should be considered when calculating the extended cost of ownership, as all batteries eventually wear out and must be replaced. The rate at which they expire depends on the type of battery technology and how they are used - many types of batteries are damaged by depleting them beyond a certain level. Lithium-ion batteries degrade faster when stored at higher temperatures.

Future

The future of battery electric vehicles depends primarily upon the cost and availability of batteries with high specific energy, power density, and long life, as all other aspects such as motors, motor controllers, and chargers are fairly mature and cost-competitive with internal combustion engine components.

Level 1, 2, and 3 charging

There are three levels of charging.

Level	Original definition
1	AC energy to the vehicle's on-board charger from the most common US grounded household receptacle, commonly referred to as a 120V outlet.
2	AC energy to the vehicle's on-board charger; 208-240V, single phase.
3	DC energy from an off-board charger; there is no minimum energy requirement but the maximum current specified is 400A and 240 kW continuous power supplied.

Charging time

More electrical power to the car reduces charging time. Power is limited by the capacity of the grid connection, and, for level 1 and 2 charging, by the power rating of the car's on-board charger. A normal household outlet is between 1.5 kW (with 110V supply) to 3 kW (in countries with 230V supply). The main connection to a house may sustain 10, 15 or even 20 kW in addition to "normal" domestic loads - though it would be unwise to use all the apparent capability - and special wiring can be installed to use this.

Faster charging

Some types of batteries such as Lithium-titanate can be charged almost to their full capacity in 10–20 minutes. Fast charging requires very high currents often derived from a three-phase power supply. Careful charge management is required to prevent damage to the batteries through overcharging.

Most people do not usually require fast recharging because they have enough time, six to eight hours (depending on discharge level) during the work day or overnight at home to recharge. Drivers frequently prefer recharging at home, avoiding the inconvenience of visiting a public charging station.

Government subsidy

Several countries have established grants and tax credits for the purchase of new electric cars depending on battery size. The USA offers a federal income tax credit up to 7,500USD, and several states have additional incentives. As of April 2010, 15 European Union member states provide tax incentives for electrically chargeable vehicles, which consist of tax reductions and exemptions, as well as of bonus payments for buyers of plug-ins and hybrid vehicles.

Currently available electric cars

As of early 2011 there are only a few mass production highway-capable models currently on the market; the remainder are mostly low-speed, low-range neighborhood electric vehicles, electric city cars as well as some small-scale commercial conversion of internal-combustion based vehicles.

There are also several pre-production models undergoing field trials or are part of demonstration programs.

III. Mass produced electric cars and pre-production models

Tesla Roadster

The 2-door Tesla Roadster is a battery electric vehicle sports car produced by the electric car firm Tesla Motors. The Roadster was the first highway-capable all-electric vehicle in serial production available in the United States. The roadster is powered by a electric motor, producing a maximum net power of 185 kW (248 hp). According to the US Environmental Protection Agency (EPA), the Roadster can travel 393 km on a single charge of its lithium-ion battery pack, can accelerate from 0 to 97 km/h in 3.9 sec and has a top speed of 201 km/h. Energy consumption of Tesla Roadster is 17.4kWh/100km (63MJ/100km). A full recharge of the battery system requires 3.5 hours using the High Power Connector (which supplies 70A 240V electricity).

Ford Focus Electric

The Ford Focus Electric is a 5-door hatchback electric car to be produced by Ford Motor Company. The electric car is powered by an electric motor rated at 100 kW (130 hp) and uses a 23 kWh a lithium-ion battery pack. The Focus Electric has a range of 160 km on a charge, a top speed of 135 km/h and energy consumption 20.7kWh/100km (74.6MJ/100km). The Focus Electric was awarded the2011 Green Car Vision Award at the 2011 Washington Auto Show.

Nissan Leaf

The Nissan Leaf is a five-door hatchback electric car manufactured by Nissan and introduced in Japan and the United States in December 2010. The electric car is powered by an electric motor rated at 80 kW (110 hp) and uses a 24 kWh a lithium-ion battery pack. The Leaf has a range of 117 km on EPA cycle and 175 km on the New European Driving Cycle. Nissan Leaf can accelerate from 0 to 97 km/h in 9.9 sec, has a top speed over 150 km/h and an energy consumption 21.2kWh/100km (76.5MJ/100km). Worldwide Nissan Leaf sales reached 10,100 units by late July 2011. The Leaf won the 2011 World Car of the Year, and was a finalist for the 2011 World Green Car. As of 2011 the Leaf is ranked as the most efficient EPA certified vehicle for all fuels ever.

Renault Fluence Z.E.

The Renault Fluence Z.E. is an upcoming electric version of the Renault Fluence - a compact 4-door sedan produced by the French automaker Renault. It was unveiled by Renault at the 2009 Frankfurt Motor Show. The electric car is powered by an electric motor rated at 70 kW (95 hp) and uses a 22 kWh a lithium-ion battery pack. The Fluence Z.E. has a range of 160 km on the New European Driving Cycle. The car can accelerate from 0 to 100 km/h in 9 sec, has a top speed about 135 km/h and energy consumption 12.5 kWh/100km (45MJ/100km).

Smart fortwo electric drive

Two-seater 3-door hatchback city car is powered by an electric motor rated at 55 kW (74 hp) and uses a 17.6 kWh lithium-ion battery pack. The official range is 140 kilometers, with an energy consumption of 12kWh/100km (43.2MJ/km). The Smart has a range of 140 km, can accelerate from 0 to 100 km/h in 13 sec and has a top speed 120 km/h. Smarts are available in USA for leasing at a price of 599 US$ per month for a period of 48 months and 60,000 km, plus 2,500 US$ due at signing.

Mitsubishi i MiEV

The Mitsubishi i MiEV (Mitsubishi innovative Electric Vehicle) is a five-door hatchback electric car produced by Mitsubishi Motors. The electric car is powered by an electric motor rated at 47 kW (63 hp) and uses a 16 kWh a lithium-ion battery pack. The MiEV has a range of 160 km (Japanese cycle) and 100 km (US EPA cycle) with an energy consumption of 18.7kWh/100km (67.5MJ/km). The car can accelerate from 0 to 80 km/h at 10.6 sec, top speed is 130km/h. MiEV Production had reached 5,000 units by the end of November 2010.

Th!nk City

The Th!nk City is a small two-seater or 2+2-seater highway capable electric car produced by Think Global and production partner Valmet Automotive. The electric car is powered by an electric motor rated at 34 kW (46 hp) and uses a 23 kWh a lithium-ion battery pack. The Th!nk City has a range of 160 km. The car can accelerate from 0 to 80 km/h at 16 sec, top speed is 110km/h. By March 2011 the Th!nk had sold 1,045 units worldwide. The Th!nk City retail price iss 36,495US$ before any applicable federal and local incentives.

Citroën C1 ev'ie

The Citroen C1 car is converted into a full electric car by Electric Car Corporation PLC. The electric car has been given the name Citroen C1 EV’ie. The combustion engine is replaced with a 30 kW (40 hp) electric motor. The fuel tank is replaced by 25 Lithium-ion batteries with a total capacity of 16 kWh. The Citroen C1 EV’ie has a range of 110 km, accelerate from 0 to 96 km/h in 15 sec, a top speed 96 km/h and an energy consumption 14.4kWh (51.9MJ)/100km.

Buddy

Buddy is a Norwegian electric car, produced by Pure Mobility. In 2010, Pure Mobility is launching its EV in 10 different new country markets, with production being ramped up to 1,200 units per annum at a net price of the equivalent of 21,250€ (about 29,000$) in Norway. The electric car is powered by an electric motor rated at 13 kW (130 hp) and uses a 13 kWh a lithium-ion battery pack. The Buddy has a range of 100 km on a charge and a top speed of 90 km/h.

Wheego Whip LiFe

The Wheego Whip is a 2-door hatchback all-electric city car originally developed as the electric version of the Chinese Noble. The production version, called Wheego Whip LiFe, was presented at the 2010 Los Angeles Auto Show and is sold in the United States at a price of 32,995$. The electric car is powered by an electric motor rated at 45 kW (60 hp) and uses 30 kWh lithium iron phosphate battery pack. The car has a range of 160 km and top speed 105km/h.

Specification of the currently available on the market electric cars and pre-production models are presented In the table below.

Table A: Specification of the currently available on the market electric cars and pre-production models

	Tesla Roadster	Ford Focus Electric	Nissan LEAF	Renault Fluence Z.E	Smart fortwo electric drive	Mitsubishi i MiEV	Wheego Whip LiFe	Th!nk City	Citroën C1 ev'ie	Buddy
Manufacturer	Tesla Motors	Ford Motor Comporation	Nissan	Renault	An automotive branch of Daimler AG	Mitsubishi Motors	Shuanghuan Automobile and Wheego Electric Cars Inc.	Think Global	Electric Car Corporation	Pure Mobility (former Elbil Norge AS)
Production	2008–present	Planned late 2011	2010–present	Planed in 2011	Planed in 2011	2009–present	2011	2008–2011	2009-present	2010–present
Body style	2-door Roadster	5-door hatchback	5-doors	4-door sedan	2-passenger, 3-door hatchback	5–door hatchback	2-door hatchback	two-seater or 2+2-seater	3 or 5 doors	3-seat hatchback
Electric power of a motor	185 kW (248 hp)	100 kW (130 hp)	80 kW (110 hp)	70 kW (95 hp)	55 kW (74 hp)	47 kW (63 hp)	45 kW (60 hp)	34 kW (46 hp)	30 kW (40 hp)	13 kW (16 hp)
Lithium ion battery, kWh	53	23	24	22	17.6	16	30 kWh lithium iron phosphate battery	23	16	13
Range, km	393 (US EPA)	160 (Ford cycle)	117 (US EPA) 175 (NEDC) 76 - 169 (Nissan)	160 km NEDC	140	160 (Japan) 100 (US EPA)	160	160	110	100
Wheelbase, mm	2,352	2,649	2,700	2,701	1,867	2,550	2,025	1,970	2,340	NA
Length, mm	3,946	4,359	4,445	4,748	2,695	3,395)	3,010	3,143	3,430	2,440
Width, mm	1,873	2,060	1,770	1,813	1,560	1,475	1,605	1,658	1,630	1,430
Height, mm	1,127	1,466	1,550	1,458	1,542	1,600	1,600	1,596	1,494	1,440
Curb weight, kg	1,235	1,674	1,521	1,543	942	1,080	1,210	1,038	890	785
Economy: in urban,	17.4 kWh/100km 63.0 MJ/100km	20.7 kWh/100km 74.6MJ/100km	21.25 kWh/100km 76.5MJ/100km	NA	12 kWh/100 km 43.2 MJ/100km	18.7 kWh/100km 67.5 MJ/100km	NA	NA	14.4kWh/100km 51.9MJ/100km	NA
Top speed, km/h	201	135	over 150	135 km/h	120 km/h	130	105	110	96	90
Acceleration	97 km/h at 3.9 s	NA	97 km/h at 9.9 s	100km/hr in 9 s	100 km/h at 13 s	80 km/h at 10.6 s	NA	80 km/h at 16 s	96 km/h at 15 s	50 km/h at 7 s
Price, US$	109,000 (USA) 115,500 (Europe)	30,000 - 37,000	32,000-36,000, USA 47,000-56,000 (Eur.)	around 31,000	About 44,800	Ab. 28,000 (USA) 41,900-44,400 (Eur.)	33,000	36,500 (USA) 38,000 (Europe)	30,890	29,000
Price per hp, US$/hp	440 (USA) 466 (Europe)	231 - 285	291–327 (USA) 427–509 (Europe)	326	605	444 in USA 665–705 (Europe)	550	703 in USA 826 in Europe	772	1813

IV. Nissan Leaf

As of 2011 the Leaf is ranked as the most efficient US EPA certified vehicle for all fuels ever.

1. Introduction

The Nissan Leaf (LEAF - *Leading, Environmentally friendly, Affordable, Family car*) is a five-door hatchback electric car manufactured by Nissan and introduced in Japan and the United States in December 2010. The United States Environmental Protection Agency (US EPA) rated Leaf's official range at 117 km, with an energy consumption of 76.5MJ/100km (21.25kWh/100km) and rated the Leaf's combined fuel economy at 99 miles per gallon gasoline equivalent (78.3MJ/100km or 21.75kWh/100km). 1 mile=1,609 meter, 1US gallon=3.78 liters). Leaf has a range of 175 km on the New European Driving Cycle (NEDC).

2011 Leaf's frontal view

2011 Leaf's rear view

Manufacturer	Nissan
Production	2010–present
Body style	5-door hatchback
Electric power of a motor	80 kW (110 hp) synchronous motor
Battery	24 kWh lithium ion battery
Range, km	117 (US EPA); 175 (NEDC); 76-169 (Nissan)
Wheelbase, mm	2,700
Length, mm	4,445
Width, mm	1,770
Height, mm	1,550
Curb weight, kg	1,521
Economy: in urban,	21.25 kWh/100km; 76.5MJ/100km
Top speed, km/h	over 150
Acceleration	97 km/h at 9.9 s
Price, US$	32,000-36,000 (USA); 47,000-56,000 (Europe)
Price per hp, US$	291 – 327 (USA); 427 – 509 (Europe)

* hp - the *metric horsepower*, 1 hp=75 x 9.80665 Newton/sec=735.5 watt.

The prices in table include the price of the battery package. Most countries have applicable tax incentives or subsidies for eligible buyers that reduce the effective cost of purchase below the retail prices.

2. Powertrain

Nissan Leaf has a top speed of over 150 km/h. Its motor is rated at 80kW or 110 hp. Unofficially, 0 to 97 km/h performance has been tested at 9.9 seconds.

The Leaf uses a front-mounted electric motor driving the wheels, powered by 86MJ (24 kWh) lithium ion battery pack rated to deliver up to 90kW (120 hp) power. The battery and control module together weigh 300 kg. Each battery pack costs Nissan an estimated US$18,000 (as of May 2010). Under its five-cycle testing, the US EPA found the Leaf's energy consumption to be 765 kJ/km (0.2125kWh/km).

3. Battery

The 24 kWh battery pack consists of 48 modules and each module contains four cells, a total of 192 cells. Since the battery is the heaviest part of car, Nissan housed the battery pack below the seats and rear foot space to keep the center of gravity as low as possible and also results in increased structural rigidity as compared to a conventional five-door hatchback.

The battery pack is expected to retain 70-80% of its capacity after 10 years but its actual lifespan depends on how often fast charging is used and also on environmental factors. Nissan stated the battery has a "lifespan of 5–10 years under normal use". The Leaf's battery is guaranteed for 8 years or 160,000 km. The Leaf's battery warranty covers defects in materials and workmanship, but does not cover gradual loss of battery capacity, nor does it cover damage or failure resulting from not following the preventive actions recommended in the Leaf Owner's Manual for the lithium-ion battery:

- Avoid exposing a vehicle to ambient temperatures above 49 °C for over 24 hours.
- Avoid storing a vehicle in temperatures below −25 °C for over 7 days.
- Avoid exceeding 70 to 80% state of charge when using frequent (more than once per week) fast or quick charging.
- Allow the battery charge to be below at least 80% before charging.
- Avoid leaving the vehicle for over 14 days where the Li-ion battery available charge gauge reaches a zero or near zero (state of charge).

4. Range

According to Nissan, the Leaf's expected all-electric range is 160km on the US EPA city driving cycle. However, the US EPA official range is 117km based on the five-cycle tests using varying driving conditions and climate controls. The Federal Trade Commission (FTC), which is supposed to label all alternative-fuel vehicles, disagrees with the EPA rating, and considers that the correct range is within 154km - 180km. Although the FTC does not conduct its own tests as EPA does, it relies on a standard set by SAE International and the results reported by automakers. The Leaf has a range of 175 km on the NEDC.

Based on third-party test drives carried out in the US, reviewers have found that the range available from a single charge can vary up to 40% in real-world situations. Reports vary from about 100km to almost 222km depending on driving style, load, traffic conditions, weather (i.e. wind, atmospheric density), and accessory use. Nissan tested the Leaf under several scenarios to estimate real-world range figures, and obtained a worst case scenario of 76km and a best case scenario of 222km. The table summarizes the results under each scenario tested using EPA's test cycle and presents EPA rating as a reference:

Driving condition	Speed		Temperature		Total Drive Duration	Range		Air conditioner
	mph	km/h	°F	°C		mi	km	
Cruising (ideal condition)	38	61	68	20	3 hr 38 min	138	222	Off
City traffic	24	39	77	25	4 hr 23 min	105	169	Off
Highway	55	89	95	35	1 hr 16 min	70	110	In use
Winter, stop-and-go traffic	15	24	14	−10	4 hr 08 min	62	100	Heater on
Heavy stop-and-go traffic	6	10	86	30	7 hr 50 min	47	76	In use
EPA five-cycle tests	n.a.					73	117	Varying

Consumer Reports tested a Leaf loaner under cold-weather driven as a daily commuter. The average range obtained was 105 km per charge with temperatures varying from -7 to -1 °C. Also reported one trip under a temperature of −12 °C that began with the range panel indicator showing 32 km remaining. After 13 km the Leaf drastically lost power and dropped its speed and continued to run slower until the last stretch was completed almost at walking speed. Consumer Reports concluded that the Leaf works as designed under cold temperatures but a more accurate range indicator is desirable.

In June 2011 Nissan reported that most Leaf owners in Japan and the United States drive distances less than 100 km per day. Nissan also found that on average owners charge their electric cars for two hours a night, and occasionally some owners drive two days on one charge.

5. Recharging

The Leaf has two charging receptacles: a standard connector for level 1 and 2 recharging [120/220V AC (Alternating current)] and a Level 3 DC (Direct current) connector, DC fast charging (480V DC 125A).

The Leaf's charging port with two inlets is located at the front of the car. Using the on-board 3.3kW charger the Leaf can be fully recharged from empty in 8 hours from a 220V, 30A supply (5.2kW allowable draw) that can provide the on-board charger its full 3.3kW of usable power.

In USA and Japan using a standard household outlet (120V, 15A breaker, 12A maximum allowable draw, 1.4kW) and the 7.5-meter cable included by Nissan, the Leaf will regain approximately 8km of range per hour. This type of charging is intended for convenience use when making stops or for emergency charging if you are within a short range of the charging destination.

Using DC fast charging, the battery pack can be charged to 80% capacity in about 30 minutes. Nissan developed its own 500V DC fast charger that went on sale in Japan for around US$16,800 in May 2010 and plans to install 200 at dealers in Japan. Nissan warns that if fast charging is the primary way of recharging, then the normal and gradual battery capacity loss is about 10% more than regular 220V charging over a 10-year period. Nissan plans to double the power of the on-board charger to 6.6kW (8.9 hp) by sometime in 2012. They are also studying the possibility of offering upgrades for the 2011 year model.

6. Technology

The Nissan Leaf employs an advanced *telematics system* which sends and receives data via a built-in *General packet radio service* radio similar to the connectivity of mobile phones. The system is connected any time the car is in range of a cell tower and it makes possible several user functionalities, such as position and possible range on a map and which charging stations are available within range. The system also tracks and compiles statistics about distance traveled and energy consumption and produces daily, monthly and annual reports of these and several other operational parameters. All information is available in the Leaf's digital screens. Users' mobile phones can be used to turn on the air-conditioner and heater, and reset charging functions even when the vehicle is powered down. This remote functionality can be used to pre-heat or pre-cool the car prior to use while it is still charging so that less energy from the battery is used for climate control. An on-board remote-controlled timer can also be pre-programmed to recharge batteries at a set time such as during off-peak rates.

Due to significant noise reduction typical of electric vehicles that travel at low speeds, the Leaf includes digital warning sounds, one for forward motion and another for reverse, to alert pedestrians, the blind, and others of its presence. For this purpose Nissan created the Vehicle Sound for Pedestrians (VSP) system. The system developed makes a noise easy to hear for those outside in order to be aware of the vehicle approaching, but the warning sounds do not distract the car occupants inside.

7. Safety

The Nissan Leaf qualified as winner of "Top Safety Pick" by the Insurance Institute for Highway Safety (IIHS). The Leaf received the top ratings of "Good" for front, side, and rear impact crash tests, and also on rollover protection. All injury measurements except one were rated good, indicating a low risk of significant injuries in crashes according to the scale of severity employed in the IIHS's testing. The European New Car Assessment Programme (Euro NCAP) awarded the Leaf the highest five star car safety rating. The Leaf earned an 89% rating for adult safety, an 83% rating for child protection and an 84% rating for its on-board safety assist systems. It also earned a higher-than-average 65% score for pedestrian safety.

8. Production

The first vehicles sold in the US were produced at Nissan's plant in Japan, which started production on October, 2010. The plant has an annual production capacity of 50,000 vehicles. In 2001 Nissan stated that 10,000 Leafs would be produced by the end of March, and production would reach 4,000 cars per month.

Commercial US production is slated to begin in late 2012 at Nissan's manufacturing facility in Tennessee. The plant will be modified with a US$1.4 billion loan granted by the US Department of Energy to allow the manufacturing plant to produce the Nissan Leaf and its advanced batteries. The plant is expected to produce up to 150,000 vehicles and 200,000 battery packs annually.

The Leaf will also be produced at Nissan's plant in Sunderland, England, beginning in 2013. Nissan will benefit from a US$44 million grant from the British government and up to US$356 million from the European Investment Bank. The plant will produce 60,000 lithium-ion batteries a year, and it also is expected to deliver 50,000 cars a year. Once production starts at the Sunderland plant, Nissan expects to reduce the Leaf price in the European market by 2013.

9. Markets

Nissan officially introduced the Leaf in a ceremony held at its global headquarters in Yokohama on December 3, 2010. The first delivery in Japan and USA took place on December 2010. Deliveries to individual customers began in Ireland in February 2011, in the UK in March 2011, and in France in August 2011. Deliveries to corporate customers began in Portugal in December 2010, in the Netherlands in March 2011, and in Canada in July 2011. Sales to individuals are scheduled to begin in Switzerland, Spain, Belgium, and Norway in the second half of 2011, with global market availability planned for 2012. As of mid June 2011, almost 5,000 Leafs had been delivered in Japan, and about 4,800 units sold in the US through July 2011. Worldwide sales reached 10,100 units by late July 2011. According to Nissan initial availability is limited in quantities and to select markets and only for customers who made online reservations. The availability will be increased by the second quarter of 2011, with US production planned for 2012, and UK production planned for 2013.

Nissan Leaf sales price by market (without any government tax credits or grants)			
Country	**Sales price**	**Equivalent US$**	**Market launch**
Japan	¥3.76 million	46,990	December 2010
United States	US$32,780 (MY 2011)		December 2010
	US$36,020 (MY 2012)		September 2011
Portugal	€35,250	50,425	January 2011
Ireland	€34,995	50,060	February 2011
United Kingdom	GB£30,990	50,170	March 2011
Netherlands	€34,990	50,050	March 2011
Canada	CAD 38,395	40,375	July 2011
France	€35,990	51,485	August 2011
Switzerland	SFr 49,950	58,860	3rd Q 2011
Spain	€35,950	51,430	3rd Q 2011
Belgium	€36,990	52,915	3rd Q 2011
Norway	kr255,000	47,110	3rd Q 2011
Denmark	kr290,690	56,535	Early 2012
Note 1: Exchange rates as of June 21, 2011 (1€ = 1.43US$)			

Europe: The Leaf was launched in Europe in early 2011. European prices are almost 14,000US$ more than the US price. Most countries have government incentives in the point of sale. Nissan said that "*the Leaf would allow owners to save 600€ a year in fuel costs compared with an equivalent internal combustion model.*" Nissan explained that its decision to launch in the selected European countries first is due to the existing government incentives for electric cars and the ongoing efforts to deploy charging infrastructure. The Leaf will be available in the other major Western European countries by late 2011.

Japan: The price of the Leaf in Japan starts at approximately US$44,600 before any current tax breaks. The Leaf is eligible for a US$9,140 government tax credit if current incentives continue through fiscal year 2010, which reduce the net price to US$35,500. The Leaf is also exempted from the car-weight and car-acquisition taxes. Nissan offers customers various purchasing methods, including a financing program that allows consumers to pay US$28,500 and then a monthly fee of US$119, which includes electricity costs. Other services that are available include assistance from Nissan dealers to customers in the installation of charging facilities in their homes. Nissan committed to install 200V regular chargers at 2,200 Nissan dealers nationwide before December 2010; about 200 dealers would also have quick-charging facilities that provide 80% of battery capacity in less than 30 minutes. Nissan guarantees the availability of at least one quick-charge unit within a 40km radius throughout the country. The 220V quick chargers went on sale on May 2010 for US$17,800 excluding taxes and installation. The quick chargers were developed by Nissan but they also work with electric cars from other automakers. Nissan offers variants built for hot and cold climate for US$20,964 and US$18,677 respectively.

United States: Nissan began the online-only reservation process on April 2010, charging a fully refundable US$99 reservation fee that allowed customers to secure a place on the list to purchase or lease a Leaf. It limited reservations to one per household and by July 2010 it had received approximately 17,000 reservations.

By September 2010 Nissan announced it had reached 20,000 reservations, and it did not accept any more reservations for the remainder of 2010. In July 2011, Nissan stated that only 48% of Leaf reservations from the initial 2010 process materialized into firm orders.

Leaf customers have the option to buy a home charging station through Nissan at cost of around US$2,200 including installation, which was eligible for a 50% federal tax credit up to US$2,000 until December 31, 2010, and afterwards the credit was reduced to 30% up to US$1,000 for individuals and US$30,000 for commercial buyers.

The 2011 model year Leaf has two trim levels available, the SV and the SL. The SV trim level includes an advanced navigation system and Internet/smart phone connectivity to the vehicle. The SL trim level adds several convenience features, including rearview monitor, solar panel spoiler, fog lights, and automatic headlights for an additional US$940. Based on actual orders of the 2011 model, the SL trim was chosen by 95% of the buyers, and of those Leaf SLs, 90% had the DC quick charge.

The base retail price for the 2011 model year Leaf in the US is US$32,780 before any applicable tax incentives. Nissan also has 36 month lease option for US$349 a month for the SV trim and US$379 a month for the SL trim, plus an initial payment of US$1,999 in both cases. For eligible customers there is a electric vehicle federal tax credit for up to a US$7,500 established by the American Clean Energy and Security Act of 2009. The federal tax credit shrinks by automaker after it has sold at least 200,000 vehicles in the US, and then it phases out over a year. Nissan explained that it priced the Leaf lower in the US than in Japan because it wants to achieve higher sales in that market. Other state and local incentives are available and may further decrease the cost.

Based on the aggregate information compiled until late April 2011 through the telematics systems included in all Leafs and reflecting the patterns of early adopters, Nissan found that the average trip length is 11 km and the average charging time is 2 hours and 11 minutes, with most owners charging on 220V charger at their homes. Additional information compiled until mid July 2011 and based on the owners profile from more than 4,000 Leaf delivered in the US market, Nissan found that the Leaf the primary vehicle for most owners; Leaf owners drive less than 97 km a day.

10. Problems reported

In April 2011 Nissan announced that customers in the US and Japan reported problems in restarting their Leaf cars after switching the motor off. Nissan said the problem does not pose any accident risk. On April 2011 Nissan announced that the problem only affected a small proportion of Leafs. Nissan engineers identified a programming error in an air conditioning system sensor that sometimes triggers an erroneous high voltage alert when the air conditioning unit is switched on, due to the increased demand for power. The system issues an Inhibit Restart command, which does not prevent driving the vehicle, but does prevent it restarting after it is turned off. The solution requires reprogramming of the Vehicle Control Module by a Nissan dealer. Nissan announced a "service campaign" to apply the software fix to all 5,300 Nissan Leafs in operation around the world, but it was not an official recall because it was not a safety issue. The applied software update also improves the car’s on-board range calculation system, which several Leaf owners reported was overestimating the number of miles left. In addition, the update changes the state-of-charge bars display to provide a true reserve capacity; the driver now has up to five miles to find a charging spot after the car reaches the zero miles remaining mark.

11. Reception

The Leaf was enthusiastically received by consumers. There were 20,000 pre-orders in the United States for the vehicle's debut. After hitting this milestone in September 2010, Nissan stopped taking reservations in the United States until many of the initial orders had been delivered in early 2011.

In 2009, a former Tesla Motors marketing manager criticized Nissan about the cooling system chosen for thermal management in lithium-ion battery packs. He also claimed there may also be an overestimation of the 160 km range that was computed using LA-4 or "city" mode, which may underestimate the energy draw during highway driving conditions.

The American magazine *Consumer Reports* noted that while charger costs vary between US$700 and US$1,200, an at-home charger and its installation cost more than US$2,000 even for simple installations. Nissan estimates a typical charger installation costs US$2,200.

The Leaf has received awards from multiple organizations. Notable awards include the inclusion by *Time magazine* (an American news magazine) as one of the 50 best inventions of 2009. At the 2010 *Washington Auto Show*, the Leaf was given the 2010 Green Car Vision Award by the *Green Car Journal*, who noted that the Leaf "will provide the features, the styling, and the driving experience that will meet the needs of a sophisticated and demanding market, while producing zero localized emissions and requiring no petroleum fuels. Other awards received by the Leaf include the 2011 *European Car of the Year*, *EV.com's* 2011 EV of the Year, 2011 Eco-Friendly Car of the Year by *Cars.com*, it was listed among the 2011 Greenest Vehicles of the Year by the *American Council for an Energy-Efficient Economy*, and also was ranked first in *Kelley Blue Book* Top 10 Green Cars for 2011. The Leaf won the 2011 *World Car of the Year*, and was a finalist for the 2011 *World Green Car*.

V. CO_2 emissions from Nissan Leaf and analogous internal combustion engine cars

Despite the fact that (Though) the electric car is propelled by electric motor, it doesn't represent clean transport from the point of view of local and global environment protection (local air pollution and global warming).

GHG emissions from the electric car depend on the fuel and technology used for electricity generation to charge the batteries. As a rule, the used electricity is generated at least partly from fossil fuel (coal, heavy oil, natural gas etc.). For instance, if a battery is charged using electricity from the State grid, the CO_2 emission intensity of car (CO_2 emissions per km traveled) will depend on the grid emission factor (CO_2 emission per generated kWh). Consequently, the CO_2 savings from the electric cars are strongly dependent on decarburization of the electricity grid. In case of completely decarbonized grid electric car becomes almost "clean".

For the last years the energy policy of Georgia has been favorable to the climate change mitigation. The share of hydro power in total energy generation has increased from 72% in 2006 to 92% in 2010. The overall goal of the Government of Georgia is to move to 100% hydro utilization and evolve into a major regional exporter of clean electricity.

To estimate how much CO_2 emissions are decreased due to substitution of Internal Combustion Engine (ICE) cars by electric cars, emissions from Nissan Leaf and from ICE cars (Diesel engine car *Nissan Qashqai 1.5 dCi Acenta 110 hp*) and (Petrol engine car *Nissan Qashqai 1.6 Acenta 115 hp*) have been calculated. Characteristics of the above mentioned cars are given in Table 1.

Nissan Qashqai 1.5 dCi Acenta 110 hp

Nissan Qashqai 1.6 Acenta 115 hp

Table 1:

	Nissan LEAF	Nissan Qashqai 1.5 dCi Acenta 110 hp	Nissan Qashqai 1.6 Acenta 115 hp
Manufacturer	Nissan	Nissan	Nissan
Production	2010–present	2010–present	2008-2010
Body style	5-door hatchback	5-door hatchback	5-door hatchback
Motor	80 kW (110 hp) synchronous	110 hp, Diesel engine	115 hp, Petrol engine
Battery	24 kWh lithium ion battery	-	-
Range, km	117(EPA); 175 (NEDC); 113; 76 - 169 (Nissan)	-	-
Wheelbase, mm	2,700	2,630	2,630
Length, mm	4,445	4,330	4,315
Width, mm	1,770	1,783	1,783
Height, mm	1,550	1,606	1,606
Curb weight, kg	1,521	1,305	1,272
Fuel	-	Diesel oil	Gasoline
Economy: in urban	21.25 kWh/100km; (76.5MJ/100km)	5,9 l/100km; (211.1MJ/100km)	8,4 l/100km;(277.2 MJ/100km)
Top speed, km/h	> 150	177	175
Acceleration	97 km/sec in 9.9 sec	100 km/sec in 12.4 sec	100 km/sec in 12.0 sec
Price, US$	32,000-36,000 (USA) 47,000USD-56,000 (Europe)	about US$30,000	about US$26,000

Specific CO_2 emissions from the ICE cars (Diesel engine and Petrol engine) in urban conditions have been calculated by formulas:

$$SPE_{Diesel} = FC_{Diesel} * \square_{Diesel} * NCV_{Diesel} * EC_{Diesel} * 44/12, \qquad (1)$$

$$SPE_{Petrol} = FC_{Petrol} * \square_{Petrol} * NCV_{Petrol} * EC_{Petrol} * 44/12, \qquad (2)$$

where

SPE_{Diesel} , SPE_{Petrol}	Specific emissions (grCO_2/km) for Diesel and Petrol engine cars ,
FC_{Diesel} , FC_{Petrol}	In urban fuel economy (liter/km) for Diesel and petrol engine cars,
$\square_{Diesel}$, $\square_{Petrol}$	Density respectively of Diesel and Petrol (kg/liter),
EC_{Diesel} , EC_{Petrol}	Carbon content of Diesel and Petrol (grC/MJ),
NCV_{Diesel} , NCV_{Petrol}	Net Calorific Value of Diesel and petrol (MJ/kg).

According to the table 1 FC_{Diesel} = 0.059 liter/km; FC_{Petrol} =0.084 liter/km;

$\square_{Diesel}$ =0.832kg/liter; $\square_{Petrol}$=0.745 kg/liter;

NCV_{Diesel} =43 MJ/kg; NCV_{Petrol} =44.3 MJ/kg (2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy. Chapter 1: Table 1.2)

EC_{Diesel} =20.2grC/MJ; EC_{Petrol} =18.9 grC/MJ (2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy. Chapter 1: Table 1.3)

Calculated specific emission from Diesel and Petrol engine cars are:

SPE_{Diesel}=156 grCO_2/km; SPE_{Petrol}=192 grCO_2/km

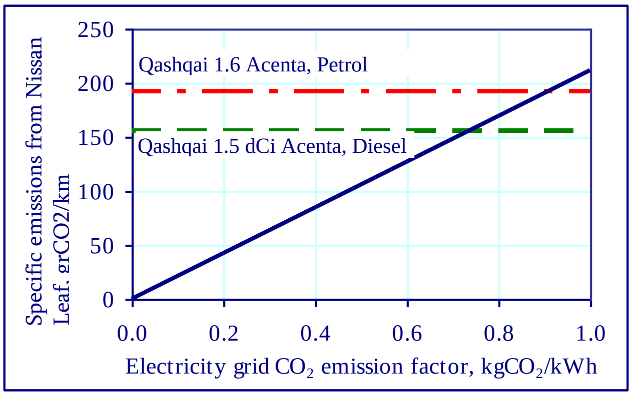
The dependence of the specific CO_2 emission factor of the electric car (Nissan LEAF) on the grid emission factor is calculated by formula:

$$SPE_{Electric} = EL_{Consumption} * EF_{Grid}$$

where

$SPE_{Electric}$	Specific emission for electricity car - (grCO_2/km),
$EL_{Consumption}$	Economy (electricity consumption) in urban (kWh/km);
EF_{Grid}	Grid emission factor (kgCO_2/kWh)

According to the table 1 $EL_{Consumption}$ =765kJ/km=0.2125kWh/km. Fig.1 illustrates the dependence of specific CO2 emissions from Nissan Leaf on State electricity grid emission factor. CO_2 specific emissions from Nissan Leaf equals to (1) the specific emissions from Diesel engine car (SPE_{Diesel} =156gCO_2/km) at grid emission factor of 0.7357kgCO_2/kWh and (2) to the specific emission from Petrol engine car (SPE_{Petrol} =192gCO_2/km) at grid emission factor of 0.9047kgCO_2/kWh. Broken line corresponds to the Diesel engine car and broken-dotted line to the Petrol engine car.



The CO_2 emission reduction due to driving with electric car instead of ICE cars has been calculated with following formula:

$$ER_{annual} = (SPE_{Diesel} - SP_{Eelectric}) * L_{annual}$$

where L_{annual} is car's annual mileage. Three values have been considered: L_{annual} = 10,000 km; 15,000 km; and 20, 000 km. According to the expert judgments L_{annual} =20,000 km for (in) USA is and L_{annual} =13,500km for (in) UK. The value of L_{annual} has not been estimated for Georgia. L_{annual} depends on the car's purpose. Obviously, the annual range of a taxi exceeds the annual range of a privately owned car.

The annual CO_2 emissions from ICE cars are given in Table 2.

Table 2: The annual CO_2 emissions from ICE cars, tons CO_2

Diesel Engine car			**Petrol Engine car**		
10,000km	15,000 km	20,000 km	10,000 km	15,000 km	20,000 km
1.56	2.34	3.12	1.92	2.88	3.84

Annual CO_2 emission reduction due to (related to) the replacement of ICE cars with electric car depends on the emission factor of electricity source. Table #3 provides information about (1) Annual emissions from electric cars and 2) Dependence of the annual CO_2 emissions reduction due to replacement of ICE cars with electric car on the emission factor of electricity source (see also Table 2). According to this Table maximum reduction is achieved if petrol engine car is replaced with electric car that is totally supplied with renewable energy based electricity.

Table 3: The annual CO_2 emissions from the electric car and the dependence of the annual emission reduction due to replacement of ICE cars with electric car on the electricity source (State electricity grid) emission factor

Grid EF, $kgCO_2/kWh$	**Annual CO_2 emissions from electric car, tones CO_2**			**Annual emission reduction (tCO_2) due to replacement of electric car by**					
				Diesel engine car			**Petrol engine car**		
	10,000 km	**15,000 km**	**20,000 km**	**10,000 km**	**15,000 km**	**20,000 km**	**10,000 km**	**15,000 km**	**20,000 km**
0.00	0.00	0.00	0.00	1.56	2.34	3.12	1.92	2.88	3.84
0.10	0.22	0.32	0.43	1.35	2.02	2.69	1.71	2.56	3.41
0.20	0.43	0.64	0.85	1.14	1.70	2.27	1.50	2.24	2.99
0.30	0.64	0.96	1.28	0.92	1.38	1.84	1.28	1.92	2.56
0.40	0.85	1.28	1.70	0.71	1.07	1.42	1.07	1.61	2.14
0.50	1.07	1.60	2.13	0.50	0.74	0.99	0.86	1.28	1.71
0.60	1.28	1.91	2.55	0.29	0.43	0.57	0.65	0.97	1.29
0.70	1.49	2.24	2.98	0.07	0.11	0.14	0.43	0.65	0.86
0.80	1.70	2.55	3.40	-0.14	-0.21	-0.28	0.22	0.33	0.44
0.90	1.92	2.87	3.83	-0.36	-0.53	-0.71	0.01	0.01	0.01
1.00	2.13	3.19	4.25	-0.57	-0.85	-1.13	-0.21	-0.31	-0.41
1.10	2.34	3.51	4.68	-0.78	-1.17	-1.56	-0.42	-0.63	-0.84
1.20	2.55	3.83	5.10	-0.99	-1.49	-1.98	-0.63	-0.95	-1.26

VI. The cost-effectiveness of electric car

There arise a question how financially attractive it might be for a person or for an organization to buy electric car instead of internal combustion car (either with diesel or petrol engine). For this reason financial evaluations have been conducted.

According to Nissan the Nissan Leaf's battery is guaranteed for 8 years or 160,000 km after which it should be replaced. It is supposed, that an electric car covers up to 20,000km per year. Therefore, the calculations have been done for 8 year period.

Following factors have been taken into account during the calculations:

- Electricity consumption of Nissan LEAF is 0.2125 kWh/km;
- In urban fuel consumption of diesel engine car (Nissan Qashqai 1.5 dCi Acenta 110 hp) is 0.059 liter/km;
- In urban fuel consumption of petrol engine car (Nissan Qashqai 1.6 Acenta 115 hp) is 0,084 liter/km;
- The electricity tariff in Georgia is 18 tetri/kWh (USD 0.109 kWh);
- Diesel price in Georgia is 2.2 GEL/liter (US$1.333/liter);
- Petrol price in Georgia is 2.2 GEL/liter (US$1.333/liter);
- Discount rate is 10%.

According to Nissan the approximate maintenance costs for electric car amounts to US$30 per month, while for the petrol or diesel engine cars maintenance costs is much more and almost US$100 per month. For more reliability (conservativeness) of conclusions the calculations have been conducted on less different values. US$40 (US$480/year) and US$80 (US$960/year)

Several options have been discussed:

Option 1: The electric car is charged by the own charger

The price of charger – about US$2,000 is included in the car's price. According to calculations the annual operational costs for electric car amounts to US$944 (US$464 electricity costs plus US$480 maintenance costs), for diesel engine car - US$2,533 (US$1,573 fuel costs plus US$960 maintenance costs), and for petrol engine car - US$3,200 (US$2,240 fuel costs plus US$960 maintenance costs). The operational costs are given below in tables 4-6.

Table 4: Operational costs of electric car

Range, km	Electricity					Maintenance costs, US$/year	Operational costs, USS
	Consumption per km, kWh/km	Annual consumption KWh	Tariff		Annual costs, US$/year		
			GEL/kWh	US$/kWh			
20,000	0.2125	4,250	0.18	0.1091	464	480	944

Table 5: Operational costs of diesel engine car

Range, km	Diesel					Maintenance costs, US$/year	Operational costs, US$
	Fuel rate, liter/km	Annual fuel consumption, liter	Fuel price		Fuel costs, US$/year		
			GEL/liter	US$/liter			
20,000	0.059	1,180	2.2	1.333	1.573	960	2,533

Table 6: Operational costs of petrol engine car

Range, km	Petrol					Maintenance costs, US$/year	Operational costs, US$
	Fuel rate, liter/km	Annual fuel consumption, liter	Price		Costs, US$/year		
			GEL/liter	US$/liter			
20,000	0.084	1,680	2.2	1.333	2,240	960	3,200

In Table below eight year sum of operational costs for Nissan Leaf and ICE cars, the difference between the summarized costs and its present value (PV) are given. According to this table, the total 8 year operational costs for the electric car is by US$8,481 less than for diesel engine car and by US$12,038 less than for the petrol engine car.

Table 7:

Year	Annual operational costs, US$		
	Nissan LEAF	Diesel engine	Difference
1	944	2,533	1,590
2	944	2,533	1,590
3	944	2,533	1,590
4	944	2,533	1,590
5	944	2,533	1,590
6	944	2,533	1,590
7	944	2,533	1,590
8	944	2,533	1,590
Total	**7,549**	**20,267**	**12,718**
PV			**8,481**

Year	Annual operational costs, US$		
	Nissan LEAF	Petrol Engine	Difference
1	944	3,200	2,256
2	944	3,200	2,256
3	944	3,200	2,256
4	944	3,200	2,256
5	944	3,200	2,256
6	944	3,200	2,256
7	944	3,200	2,256
8	944	3,200	2,256
Total	**7,549**	**25,600**	**18,051**
PV			**12,038**

Let's introduce the Net Present Value (NPV) defined as PV minus the price difference between the ICE cars and electric car. Below the dependence of NPV on the price difference is given. It is supposed that the price difference is paid by the buyer while purchasing the electric car (buyer is paying the whole amount of good value, does not use the other forms of purchase, like leasing.)

On the Table 8 the dependence of NPV on the price difference between the ICE cars and electric car is presented. NPV becomes zero (meaning that financially there is no difference which of these cars a driver would use during 8 years, ICE cars or electric car), when the difference between the prices is US$8,481 for diesel engine car and US$12,038 for petrol engine car.

Table 8:

Price difference, US$	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000
NPV for Diesel Engine car, US$	8,481	7,481	6,481	5,481	4,481	3,481	2,481	1,481	481	-519				
NPV for Petrol Engine car, US$	12,038	11,038	10,038	9,038	8,038	7,038	6,038	5,038	4,038	3,038	2,038	1,038	38	-962

While charging with its own charger electric car (Nissan Leaf) will be more profitable than:

- **Petrol engine car (Nissan Qashkqai 1.5 Acenta 115 hp) if the price difference between the cars is less than US$12,038;**
- **Diesel engine car (Nissan Qashkqai 1.5 dCi Acenta 110 hp) if the price difference between the cars is less than US$8,481.**

Option 2: Charging with commercial fast charger:

Probably, fewer drivers will use fast chargers and most of them very occasionally. The 500V direct currency fast charger manufactured by Nissan now costs approximately US$1,700. This charger charges the battery by 80% in half an hour. Nissan manufactured new fast charger that is twice as small as the previous one and almost twice as cheap.

Below two hypothetical options are considered based on more or less real propositions.

The parameters of commercial charging station are:

- Station is equipped with 6 chargers and their costs including installation costs is US$60,000;
- The station building (house) cost amounts to US$40,000;
- The operational costs amounts to US$65,000, including annual salaries of US$50,000;
- One charging time lasts for 30 minutes;
- Station works for 16 hours per day including day offs.
- The load factor of station will be 65%, will serve up to 125 customers per day;
- Investment: US$100,000 loan. The interest rate - 8%, repayment period 5 years;
- VAT: 18%.
- Profit tax: 15%.
- Depreciation: 10% of fixed capital;
- Lifetime: 10 years.

The price of charging of battery was selected so that Internal Rate of Return (IRR) set equal to 20%. Under this condition charging of 24 kWh battery by 80%, or 19.2 kWh charging cost should be US$4.26. Therefore 1 kWh will cost a driver US$0.222/kWh (4.26/19.2 KWh), about 36.6Tetri/kWh. From each kWh the income for station will be 18.9Tetri (36.6Tetri minus 17.7Tetri - the price of electricity that is given to the station from the central electricity system).

According to the calculations the annual operational cost for electric car amounts of US$1,423 (US$943 electricity costs plus US$480 maintenance costs). For the diesel engine and petrol engine cars the operational costs are the same as in previous case (charging of battery with driver's own charger).

Table 9: Operational costs of electric car

Range, km	Electricity					Maintenance costs, US$/year	Operational costs, USS
	Consumption per km, kWh/km	Annual consumption KWh	Tariff		Annual costs, US$/year		
			GEL/kWh	US$/kWh			
20,000	0.2125	4,250	0.366	0.222	943	480	1,423

The table below illustrates the difference between the operational costs of electric car and ICE cars and present value of this difference in case of diesel engine and petrol engine cars:

Table 10:

year	Annual operational costs, US$		
	Nissan LEAF	**Diesel engine car**	**Difference**
1	1,423	2,533	1,111
2	1,423	2,533	1,111
3	1,423	2,533	1,111
4	1,423	2,533	1,111
5	1,423	2,533	1,111
6	1,423	2,533	1,111
7	1,423	2,533	1,111
8	1,423	2,533	1,111
Total	**11,382**	**20,267**	**8,885**
PV			**5,925**

year	Annual operational costs, US$		
	Nissan LEAF	**Petrol engine car**	**Difference**
1	1,423	3,200	1,777
2	1,423	3,200	1,777
3	1,423	3,200	1,777
4	1,423	3,200	1,777
5	1,423	3,200	1,777
6	1,423	3,200	1,777
7	1,423	3,200	1,777
8	1,423	3,200	1,777
Total	**11,382**	**25,600**	**14,218**
PV			**9,482**

On the Table 11 the dependence of NPV on the price difference between the ICE cars and electric car is presented. NPV becomes zero (meaning that financially there is no difference which of these cars a driver would use), when the difference between the prices is US$5,925 for diesel engine car and US$9,482 for petrol engine car.

Table 11:

Price difference, US$	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
NPV for Diesel Engine car, US$	5,925	4,925	3,925	2,925	1,925	925	-75				
NPV for Petrol Engine car, US$	9,482	8,482	7,482	6,482	5,482	4,482	3,482	2,482	1,482	482	-518

Using commercial fast charger, electric car would be more profitable than:

- **Petrol engine car (Nissan Qashqai 1.6 Acenta 115 hp) if the price difference between the cars is less then US$9,482;**
- **Diesel engine car (Nissan Qashqai 1.5 dCi Acenta 110 hp) if the price difference between the cars is less then US$5,925.**

Option 3: Charging of battery at noncommercial State or municipal owned charging stations

The calculations (similar to calculations in option 2) have been done taking into account the following:

- Station is equipped with 6 chargers and their costs including installation costs is US$60,000;
- Station building (house) costs approximately US$20,000;
- The operational costs amounts to US$25,000, including annual salaries of US$20,000;
- Charging time of battery is 30 minutes;
- Station operates for 16 hours every day including day offs;
- The load factor of station will be 65%, will serve up to 125 customers per day (daily);
- Investment of US$80,000 is made by government or municipality;
- VAT: 18%.
- Profit tax: 15%.
- Depreciation: 10% of fixed capital;
- Lifetime: 10 years.
- The price of charging of battery was selected so that Internal Rate of Return (IRR) set equal to 8%.

Using non commercial state or municipality owned fast charger, Nissan Leaf will be more profitable than:

- **Petrol engine car (Nissan Qashqai 1.6 Acenta 115 hp) if the difference between the prices of the cars are less then US$10,890;**
- **Diesel engine car (Nissan Qashqai 1.5 dCi Acenta 110 hp) if the difference between the prices of cars is less then US$7,340.**

Option 4: Charging at the noncommercial, state or municipality owned fast charger located in the cities or on the highways

The calculations (similar to calculations in option 2) have been done taking into account the following:

- There is one charger and its price of US$10,000 includes the installation costs;
- The operational costs amounts to US$1,500;
- Charging of one battery requires 30 minutes.
- Station operates for 24 hours including day offs.
- Load factor of station is 33%; station will serve 16 customers every day.
- Investment of US$10,000 is done by the government or the municipality.
- VAT: 18%.
- Profit tax: 15%.
- Depreciation: 10% of fixed capital;
- Lifetime: 10 years.
- The price of charging of battery was selected so that Internal Rate of Return (IRR) set equal to 8%.

Using non commercial state or municipality owned single fast charger in city or on the highway, Nissan Leaf will be more profitable, than:

- **Petrol engine car (Nissan Qashqai 1.6 Acenta 115 hp) if the price difference between the prices is less then US$11,300;**
- **Petrol engine car (Nissan Qashqai 1.5 dCi Acenta 110 hp) if the difference between the prices is less then US$7,760.**

Summary table

Type of a charger	**Price difference between electric car and ICE cars, in US$**	
	Diesel engine	**Petrol engine**
Own charger	8,481	12,038
Fast charger –option 1; commercial charging station	5,930	9,480
Fast charger – option 2: state or municipality owned non commercial charging station	7,340	10,890
Fast charger – option 3: non commercial state or municipality owned single fast charger in the city or on the highway	7,760	11,300