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Twelve Shades of Green: Contrasting the Environmental Effectiveness of Power Generation Methods in 12 Developed Countries through the Lens of the Electric Vehicle

William Deo

Presently, there is an issue with the perception of power generation mixes across the developed world. It is widely believed that by implementing electric vehicles, we will be able to reduce our carbon emissions into the atmosphere. However, while it is true that transportation and power generation are the two largest emitters of carbon, the electrification of vehicles will simply lead to an increase in our demand for energy produced by fossil fuels. Through a comparative quantitative analysis, this study examines 12 developed and geographically diverse nations in an effort to understand the real virtual tailpipe emissions of an electric vehicle. Through the analysis, it was found that out of the 12 countries, only six would benefit environmentally from widespread electric vehicle implementation presently. Moving forward, this study highlights the importance of non-emitting power sources, emphasizing the benefits of nuclear power generation as a dependable and efficient energy source.

Introduction

The earth is on track to becoming an uninhabitable planet. Between the rise in temperatures, depletion of resources and dependency on faltering systems, we are at a crucial point in our society's development. While there are numerous issues that we must solve on our planet, one of the largest and most widespread issues is that of climate change. Presently, the two largest polluting factors in the realm of carbon emissions come from power generation and transportation (Hawkins et al., 2012). Numerous scientists point to the proliferation of electric vehicles to be our saving grace in this time of pollutants in our atmosphere – and while this does help delocalize these emissions from large urban centers, this does not positively impact our environment unless the power being generated to drive the vehicle is cleaner than that of simply driving a normal car.

This research paper aims to examine the environmental effectiveness of the power generation methods and mixes in place in 12 developed countries in an effort to see what is the ultimately the best mix of resources to generate the cleanest power at a responsible cost. This paper examines this through the implementation of a comparative quantitative analysis method that works to take into account broad ranges of power generation methods as well as compare to a traditional automobile.

Review of the Literature

Electric vehicles have potential to reduce carbon emissions, local air pollution and the reliance on imported oil (Wilson, 2013). It is with little wonder that governments around the world have supported their roll-out in recent years with carbon-saving subsidies and other benefits to owners (Nikiforuk, 2015). Although there is a widespread understanding that electric cars have the potential to release our carbon emissions, their effectiveness depends on the type electricity that they use (Hawkins et al., 2012). Knowing that over 70% of our energy today is still tied to fossil fuels (García-Gusano et al., 2016), the carbon reduction potential (the potential of emission reduction) of an electric car depends substantially on where it is used. However, presently it is not known the specific benefit or advantage of driving an electric car in a country is still partially, or fully, dependent on fossil fuels. This is what my research will demonstrate.

My research details an important gap in the field: how does the environmental effectiveness of vehicles vary across developed nations around the world. Environmental effectiveness must take into account manufacturing emissions, grid source emissions and grid loss emissions. All of which vary other than manufacturing emissions. This is valuable to evaluate which power generation mixes are most efficient for specific countries in different geographic areas for implementing electric vehicles to lower our carbon footprint. Presently, no piece of research has done this. Through adopting efficient generation methods that will be recommended through my research, we might be able to move too the most efficient electric vehicle future possible.

A survey of existing literature was conducted, and the intelligence garnered was grouped into three sections: the carbon emissions of electric cars, a comparison of electric and petrol cars and their respective sensitivity to energy use.

Carbon Emissions of Electric Cars

Lindly and Haskew (2002) reported on the impact of electric vehicles on global environmental change was one of the first studies in the field. A University of Alabama research report showed how, in regions of the world such as the mid-western United States, there would only be a decrease of 5-7% in carbon emissions though a shift to electric vehicles. The study concurred that it would ultimately be impractical to initiate such a shift to electric vehicles for such a small reduction. In 2015, Nikiforuk (2015) demonstrated that this was still the case, measuring the effectiveness of these vehicles to only be about 8.5-10% better than traditional gas-powered vehicles in the mid-west demonstrating that little has changed in the region towards clean power. This allows me to sufficiently demonstrate that there are regions of the world that are yet to adopt renewable methods of power generation and yet, there is still a benefit over traditional vehicles.

However, in other regions of the world, such as Norway, the benefit of implementing electric vehicles was up to 45% better than driving a traditional vehicle (García-Gusano et al., 2016). This was largely due to an environment that has become nearly free of fossil fuels leading to the cleaner production of energy (Wilson, 2013). Wilson (2013) also mentions the importance of different magnitudes of lost power occurring from different generation methods. In countries such as Paraguay, 100% of power is generated from hydroelectric sources (Shift Project, 2014) which has essentially zero margin of loss (Hawkins et al., 2012). Through analyzing these findings, I am able not only to connect the fact that there are different generation mixes that are more efficient, but also that there are regions of the world that have adopted essentially 100% *clean electric vehicles.*

However, this changes when examining a country like India. According to the 2014 Shift Project, in India, over 80% of energy is generated from coal and natural gas. Not only does this mean that there is a dramatic increase in the carbon emitted from the generation, but there is also a higher margin of loss (Hawkins et al., 2012). Thus, not only is there an increase in carbon emissions, but also an increase in electricity demand for the same amount of energy which results in an increased negative result. Xiao-Ling (2016) gave a similar result that shows that due to the dominance of coal generation in countries like India, South Africa, Australia, and China, grid powered electric cars actually produce comparable emissions to those of normal petrol vehicles with emissions ranging from 258-370 g of carbon per kilometer driven.

Further, S. Dotson, a professor of environmental engineering at the University of Waterloo, suggests in his report that progress is being made as countries like Canada and Brazil are adopting hydroelectricity along with countries like France adopting nuclear energy, all of which result in a range of 89-115 g of carbon per kilometer driven. However, Nikiforuk, while surveying research done by McGill University, reminds us that this is only the case in Western and industrialized countries as the vast majority of the world's energy is still generated from fossil fuels (Nikiforuk, 2015). As such, in an effort to move towards clean transportation, we must move away from traditionally methods used towards newer, more renewable technologies.

Electric Vehicles compared to Petrol Cars

When comparing petrol cars to electric vehicles to evaluate the climate benefits of electric vehicles, there are many factors to examine (Wilson, 2013). Lindly and Haskew (2002) estimated that the manufacturing emissions of a traditional vehicle are 40g of carbon per kilometer over a traditional lifespan. However, when contrasting this with the 70g from the electric vehicle generated by Notter et al. (2010), Patterson (2011), as well as Hawkins et al. (2012), this is significantly higher. This dramatic discrepancy in manufacturing emissions is due to the electric vehicle manufacturing footprint of 10.5 tons of carbon (Wilson, 2013). Notter et al. (2010) further investigated this, acknowledging that up to four tons of this carbon can be attributed to battery manufacture something that petrol vehicles do not require.

Through Wilson (2013), we are also able to see in terms of environmental effects, vehicles powered solely by hydroelectricity achieve an equivalent to one liter of petrol consumed over 100 kilometers driven nearly entirely attributed to manufacturing effects. However, countries using hydroelectricity and nuclear mixes are not far behind with equivalencies of 2.5 liters per 100 kilometers an efficiency better than the most efficient hybrid gas-electric vehicles available at market (Dotson, 2011). However, when countries like India and China are considered, their equivalencies are similar to new petrol power vehicles (Xiao-Ling et al., 2016). For instance, equivalencies range from 9-12 liters per 100 kilometers driven based on regional generation methods (Xiao-Ling et al., 2016). This is especially important to note as in my research, I attempt to provide a tangible figure that the general populous will easily understand.

However, one thing that these equivalency estimates do not account for are the relocation of pollutants to centralized locations (Lave, Hendrickson & McMichael, 1995). For instance, large cities often suffer from localized pollutants arising from vehicles (García-Gusamo et al., 2016). Lave, Hendrickson and McMichael (1995) suggest that as long as the equivalencies of these vehicles are equivalent or less than traditional vehicles, there is a positive environmental impact for large cities as pollutants are moved to power generation plants, often far from heavily populated areas. Therefore, resulting in a positive immediate environmental effect for the large cities. This is an immediate net positive effect for urban centers (where pollution is most wide-spread) and is an innate benefit for electric vehicles. However, this is difficult to implement into my research and as such, will be assumed as a pre-existing benefit.

Sensitivity to Energy Use

There is also discrepancy when it comes to the *wall-to-wheels* electricity use of a vehicle. For example, Wilson (2013) utilized a figure of 211 Wh/km (Watt-hours per kilometer) driven which is a mid-ranged figure similar to that of a Nissan Leaf (Wilson, 2013). However, other reports such as Dotson (2011) utilized a much lower energy use figure of 174 Wh/km which is similar to a small sized electric vehicle like the Scion iQ (Dotson, 2011). However, Hawkin (2012) demonstrated that for larger electric vehicles like the Toyota Rav4 EV up to 273 Wh/km is required. More recently, Lindly and Haskew (2002) examined the performance enhanced Tesla Model S P85+ which had a 231Wh/km, a very good energy consumption figure for a vehicle of its size. In my own research, this allows me to take into account the average vehicle that is being used in that specific environment. For example, in North America, we see increasingly large vehicles. However, in developing nations, we see the widespread use of much smaller vehicles. This is something that I must consider when factoring environmental efficiency to be regionally specific.

This concurs with Notter et al. (2010): battery technologies are advancing. Batteries are becoming more energetic in lighter packages. This combines for a net effect of a lower Wh/km required, proving that the future of environmental vehicles is becoming even more power efficient. This allows for an optimistic future and proves that more research is needed in the field. Since battery technologies are evolving nearly every year, research on effectivity of electric vehicles must be constantly conducted to account for new advancements.

Overall, through a thorough survey of the literature it can be concluded that there is significant evidence that the environmental effectiveness of electric vehicles varies due to power generation methods. However, the gap that is missing in the body of knowledge, is exactly what is the difference and the specific advantage to adopting renewable and zero-carbon power technologies. This is what my research attempts to discover: the specific quantifiable environmental advantages that the electric vehicle possesses as power generation mixes change.

Method

To achieve a richer understanding of the environmental effectiveness of electric vehicles a comparative quantitative analysis is employed. This method collects publicly available data in the effort to demonstrate a numerical contrast between multiple items or options. In this paper, this method is used to compare the different generation methods and mixes of methods to translate into a standard Litres / 100 Km driven figure. This is based on carbon emissions from power generation. Through comparing a relatively abstract figure of carbon emissions to the more common polluting factor of Litres / 100 Km, there will be a more tangible connection between pollution from power generation and driving electric vehicle.

Data is collected from a number of reputable resources and cross-referenced when possible to a pre-existing benchmark. This allowed for numerous measurements and the creation of an average which ultimately leads to a more reliable result. When gathering figures to contrast through the method, one of the most integral pieces of information to this analysis is the mix of power generation methods and technologies in the 12 nations that were closely observed. The number of countries examined (12) were chosen as these countries represent not only developed countries where these electric cars are most likely to be driven, but also represents a widespread geographic location where these systems are in place. In addition, through using this method, there is also a variation in the country's geographical features. Thus, when making recommendations, these can be widespread and have meaning for a large range of countries.

Secondly, it is necessary to know the amount of carbon emitted from the generation of a kilowatt of energy. Concurrently, it is necessary to know the amount of carbon emitted from the combustion of 1 litre of petrol in a similarly sized vehicle to the one that is being studied. Further, it is necessary to know the number of kilowatts of energy that are needed to drive 100 kilometres in the vehicle that is being examined. Finally, for a complete comparison, it is necessary to collect information about the carbon emitted from creating the two distinct vehicles.

Through using a quantitative method, the study will offer a more detached view and stress objectivity in the demonstration of results. Objectivity is extremely important given the heavily controversial and political repercussions of this subject with increasing, global impact. The method looks at relationships and establishes causes and effects between variables. The quantitative approach leads to overall more scientifically sound data and results as opposed to solely based on a restricted sample of qualitative test subjects. In

Country	Car Manafacturing	Grid Direct	Grid Indirect	Grid Losses	Total (g Co2/km)
India	70	242	20	38	370
South Africa	70	242	5	1	318
China	70	181	4	3	258
Turkey	70	114	7	13	204
United States of America	70	122	8	2	202
United Kingdom	70	107	6	6	189
Japan	**70**	**98**	**4**	**3**	**175**
Russia	**70**	**80**	**3**	**2**	**155**
Canada	**70**	**40**	**3**	**2**	**115**
France	**70**	**20**	**2**	**1**	**93**
Brazil	**70**	**18**	**0**	**1**	**89**
Paraguay	**70**	**0**	**0**	**0**	**70**
	Carbon Emission	Fuel Economy		Total (g Co2/km)	
Traditional Car (Ford Focus)	2770 g Co2/L	6.6 L/100Km	0.066L/Km	182.82 g/KM	

Figure 1: This table shows the total amount of CO^2 emitted per kilometer driven based on a country's power generation mix. This is contrasted with the emissions from a typical compact car, the Ford Focus.

this study, there was no involvement of human participants and as such, this research should not face any ethical qualms.

Finally, the analysis will break down the power generation methods by percentage of total generation in the country and will calculate each generation method's proportional impact of the total combined mix. This is shown in the equation below and will be repeated for all of the different power generation systems. This will be added to the set number of grams of carbon emissions from the generation of the vehicle itself. The Ford Focus was used as the benchmark gas vehicle for reasons explained in Appendix B.

$$\left(\frac{CO_{2(g)}}{kw}\right) \circ \left(\frac{kw}{100km}\right) = \textit{Virtual Tailpipe Emissions}$$

Results

Through the quantitative analysis, information was discovered that is rather contrary to the popular belief. In fact, as shown in the figure below, out of the 12 countries that were examined for environmental effectiveness of power generation systems, only 6 of them have improved environmental benefits when using them compared to traditional vehicles.

In the above table, it can be observed the clear contrast of where the electric vehicle falls in relation to the electric car. Here, the data for the electric vehicles was collected by examining a broad mix of electric vehicles (appendix b) which was then estimated to be on average the size of the Ford Focus. As such, the Ford Focus was used for control variable of the traditional vehicle.

To understand the implications are in the above chart it is important to note that while data is only available on a national scale, in large countries there is often a variance in how power is generated from region to region within the country itself. As such, in one region of the United States, power generation due to hydroelectricity, or wind might be the best available alternative, this might not be the case in another distinct region of the country.

However, it is important to see the trends of the countries that are leading the charge towards a clean, efficient future. For instance, out of the 12 countries surveyed, the cleanest energy came from Paraguay (see Appendix). In Paraguay, 100% of the electricity comes from hydroelectric sources due to the geographical features of the country. In addition, Paraguay is a relatively small country with a relatively small energy demand. In fact, the demand for energy in Paraguay is only 10% that of France, or just 1% that of China (The Shift Project, 2014). As such, due to a unique circumstance, Paraguay is able to flourish in their essentially clean production of energy.

However, when looking for a solution that is more applicable to countries that do not have the same unique makeup of Paraguay, other renewable sources enter. For instance, wind energy and bio mass power generation both play a large role in the generation of clean energy in countries like Brazil and Canada. Yet, under examination, is a very expensive and land intensive generation process while bio mass energy generation requires a high amount of supervision and training: something that developing countries cannot afford. Yet, there must be a solution, an ideal alternative that is able safe, powerful and relatively inexpensive – this solution is nuclear energy generation.

Analysis

Through analyzing the data, it is easy to see that the generation methods some of these developed countries simply do not make it economically nor environmentally feasible to switch to electric vehicles. Essentially in most regions of even the developed world, we are still using sub-par generation methods that belong in the twentieth century. The power mixes were analyzed and as a result, nuclear power can be recognized as a resource that is readily available and safe, yet potent and can be implemented in any region.

Other potential alternatives included the implementation of widespread hydroelectric electricity generation; however, due to the nature in which it is generated, hydroelectric power can only be utilized in certain regions of the world with permissible geographical characteristics (McInnes, 2011). Further, other low-carbon sources of power generation such as solar and wind require too large of an upfront capital investment for these options to be realistically considered to power millions of homes on a constant basis (Comby, 2014). Besides large startup costs, there would also be subsequent large investments required in massive battery systems as surplus power must be stored for times when the sun is not optimally positioned or instances where the wind is not blowing at a beneficial rate, in the correct direction for the turbine (Biello, 2013). As such, nuclear energy is, at present, the most viable method to decrease our carbon emissions without having to drastically alter our energy demands.

Nuclear energy is a way to potentially disassociate our dependence on the environment for energy. Due to the potency of the nuclear fuel and its ability to be used repeatedly once it is spent, there is essentially no reliance upon external factors here (Fountain, 2017). This energy source has a much smaller footprint as it requires much less material and refining than other types of traditional and especially alternative renewable solutions. By using nuclear energy in a widespread manner, we can drive down the costs as governments will be able to limit the number of designs through understanding which designs are the correct build and fit for their needs (Biello, 2013). Further, with widespread implementations, we can essentially eliminate our dependence of carbon and methane emission down to nearly atmospheric levels.

Many argue that the process of extracting the Uranium from the earth is process that is detrimental to the environment. However, it is important to note that this is the same process that is undergone to extract coal. In addition, the amount of fuel needed to be extracted is dramatically less when compared to the tons of coal being burned (Comby, 2014).

Presently, Nuclear energy is created through the process of Uranium fission, though new technologies are in development for Helium fusion processes (Levitan, 2016). Uranium has many isotopes, one of which, Uranium-234, has an extremely unstable nucleus. Through an extremely exothermic process, the nucleus breaks down resulting in the emission of heat, but also activating further chain reactions (Williams, 2013). These subsequent reactions operate on a factor of three such that each fission event is able to trigger three more if not moderated (Williams, 2013). This process of fission liberates large amounts of energy, which is then transferred to electric potential energy through the process of steam generation in a process similar to that in a coal fired generation plant. While this process, if not monitored properly, can lead to potential catastrophes, with proper control and moderation, this source of energy could be the solution to our global energy crisis (Biello, 2013).

As an industrialized civilization, the amount of energy we require is constantly growing. Currently, over 85% of that energy is provided by burning fossil fuels like coal, oil and gas on a global scale. While there is potential for coal to last us for many centuries into the future, the amount of greenhouse gasses emitted especially carbon dioxide and carbon monoxide are not conducive to an environmentally sustainable nor efficient future (Comby, 2014). While natural gas developed as a byproduct of oil extraction, it has grown in popularity since through a completely clean combustion the only by products that result are Carbon Dioxide and Water; however, this is seldom the case (Levitan, 2016). Saying this, our reserves of natural gas are extremely limited and are unlikely to last into the 22nd century.

In burning coal and natural gas, we lance approximately 23 billion tons of carbon dioxide into Earth's atmosphere each year, roughly the equivalent to 4 400 tons per minute. While a fraction of this polluting gas is absorbed by vegetation, nearly 40% is absorbed by seas leading to detrimental ocean acidification (Fountain, 2017) which has its own resulting detriments. For the other percentage, totaling nearly 60%, it remains in the atmosphere – altering its compositions and affecting our global climate.

While this encompasses the broader and increasingly complex issue of global climate, climate change and global warming, it is important to realize that power generation is one of the largest contributors to greenhouse gasses, which is the main factor in climate altering effects. Presently, we only have this planet to live on. As we aim to keep our planet a viable and livable environment whilst ensuring the modern necessities we have become accustomed to, we are in need of the adoption of new energy sources (Comby, 2014).

Nuclear power checks all of the boxes when examining and probing for a substantial alternative to the dark destination that we are presently on track towards. Nuclear energy is much cleaner than is widely understood. It produces no carbon dioxide in its actual fission (energy generating) process along with no sulfur dioxide or nitrogen oxides, which are large contributors to ocean acidification. These gases are produced in dramatic excess when fossil fuels, such as coal, natural gas or petroleum, are combusted (Comby, 2014).

The major complaint when it comes to the issue of nuclear power is the waste that is created in the form of spent fuel. However, it is important to understand the *factor of one million.* In essence, this is the basic understanding that one gram of uranium yields as much energy as a ton of coal when combusted at standard efficiencies (McInnes, 2011). As such, nuclear waste is one million times smaller than fossil fuel waste and is entirely confined to the generation chamber – no escaping pollutants into the atmosphere and oceans (Anderson, 2015).

In countries where older methods of nuclear energy generation are in use such as the United States of America and Russia, spent fuel is simply stored in isolation or disposed of through a borehole disposal process. However, in countries such as Germany and France spent fuel is reprocessed to separate out the radioactive fission products while the remaining materials are recovered and recycled into new energy (Anderson, 2015). Further, technologies in Scandinavian countries and Canada utilize unenriched Uranium fuel in an extremely controlled manner to produce spent fuel that can be used numerous times and then stored in a pool for extended amounts of time, after this, they are safe for natural disposal (McInnes, 2011). Of course, the downside to this process being the relatively small yield of energy per generator due to the lack of enriched fuel.

Further, when examining the tremendous efficacy and potency of nuclear energy, it was found that a typical family of four over their entire lifespan would be hard-pressed to use more than a golf ball's size of uranium to power their lives. This is dramatically different from the tons of gas that are emitted through smoke stacks causing global warming, acid rain, smoke and other forms of atmospheric pollution (Comby, 2014).

Nuclear reactors are also reliable, durable and resilient meaning that they are available for often over 90% of the time of their service life. With under 10% of time being used for maintenance and refueling, this is better than the yield of any traditional source (Comby, 2014). Further, in the United States, improvements have been made so the lifespan of plants are designed for 40 years, which often are granted further 20-year extensions as they remain within safe operational parameters. Of course, while it is possible for traditional coal plants to surpass these figures, old plants would not be near to the level of efficiency and levels of technology that comparable new plants would be at (Spencer, 2011). Essentially a detriment both economically and environmentally.

Continuing, the cost of the fuel in a nuclear plant is a small fraction of the price of the total energy, whereas fossil fuel prices are essentially at the will of the market due to a large portion of their generation costs going towards raw material expenses (McInnes, 2011). In addition, uranium is available in abundance on the crust of the earth. In fact, the element is more abundant than tin and large deposits exist in Canada and Australia all while new deposits and methods of extraction are being examined (Williams, 2013). Further, new technologies are evolving where uranium is collected from seawater where an estimated 4 billion tons could be extracted. Nuclear power stations are also more compact than any of its modern alternative generation methods (Spencer, 2011). A nuclear power station takes up just roughly the area of a small football stadium while solar farms and wind turbines both require square kilometres of land (Comby, 2014).

Most of the opposition when it comes to nuclear power is a result of the ignorance over two major misconceptions that are conveyed by ecological organizations with opinions grounded more so in ideology than fact. These misconceptions are: the amount of radiation absorbed by being in the vicinity of a power plant, along with the potential for disaster (Levitan, 2016). Campaigns have been established to harp on peoples' mystery towards radiation. A very small sector of the population is in fact cognizant of the fact that radiation is naturally occurring everywhere in our environment. In fact, moderate radiation amounts is natural and studies have shown it to be moderately beneficial to healthy human life (Anderson, 2015).

Everything around us is radioactive in nature to a certain degree and has been so for millions of years, long before our implementation of nuclear energy (Comby, 2014). In fact, when life first occurred on earth, geologists estimate that natural radiation levels were nearly twice what they are today (Anderson, 2015). Additionally, the human body is radioactive in itself. Our bodies contain about 8000 atoms disintegrating each second (Comby, 2014).

Further nuclear power is safe, and this needs to be emphasized. This has been demonstrated by the over 12, 000 combined years of reactor function which have transpired over the past half century with only two major isolated incidents (Three Mile Island and Chernobyl) as well as only one extreme weather-related incident (Fukushima) (Comby, 2014).

In short, nuclear power is well positioned to be our future of our energy security. Through well designed, well-constructed, well operated and well-maintained facilities, nuclear energy is clean, safe, reliable, competitive and durable. Nuclear energy remains our best positioned resource as a society aiming to move towards a future free of greenhouse gas emitting sources while still maintaining high levels of efficiency and a high demand for electricity. Not only does nuclear energy provide us with an option that is viable for quick entry into our power grid with quick turnaround times, but it also offers a solution that is cost effective and is beneficial to economies in both the short and long term. As we see the trend of increasing energy demand, and there is no reason to foresee a slowing of this, we need to move with the vision of clean, safe, and efficient manners of electricity generation. Nuclear power can fulfill that vision.

Conclusion and Future Actions

The results of this study highlight the subpar levels of effectiveness that our current power generation systems have on the proliferation of electric cars on a global scale. From the viewpoint of the electric car it is obvious to see that if we continue down the path that we are currently heading, it will not be environmentally effective to implement electric cars. Therefore, if our society is aiming to move towards the implementation of these vehicles further research must be conducted into the specific regional benefits of these power generation methods. Furthermore, if this study was conducted on a broader scope that would encompass not only the developed world, but countries that are now building robust energy grid systems, this might aid them in developing clean energy. Through this, they will not have to go through a revision process as much of the developed world has gone through and continues to go through. Further, the recommendations made through the research here are not necessarily the only actions possible for these countries; whereas, in certain countries other renewable sources may be advantageous.

Despite the unfavorable results that were discovered through the comparison of power generation methods, it is entirely possible for our society to become less carbon dependent in a relatively short period. By coupling the two largest environmentally polluting industries (power generation and transportation (Wilson, 2013) and implementing electric vehicles as well as environmentally responsible power systems we will be able to move towards a brighter, more green future in the spirit of progress.

Appendix A

This chart shows the breakdown of the percentage of energy from numerous sources. In the chart, the total amount of power generated can also be observed. These vary drastically within these developed countries from Paraguay at 57 TWh up to China at 5145 TWh. (Shift Project, 2014)

Country	Total 2014 (TWh)	% from Wind	% from Nuclear	% from Hydroelectric	% from Gas	% from Coal	% from Oil	% from Biomass	% From Others
India	1117	3.13%	2.95%	11.55%	7.97%	71.62%	0.00%	0.00%	2.78%
South Africa	243	0.00%	6.17%	0.41%	0.00%	92.59%	0.82%	0.00%	0.00%
China	5145	2.88%	2.55%	20.00%	1.77%	71.55%	0.00%	0.00%	1.26%
Turkey	223	4.04%	0.00%	17.94%	46.19%	30.04%	0.90%	0.00%	0.90%
United States of America	4255	4.28%	18.73%	6.09%	29.89%	37.88%	0.00%	0.00%	3.13%
United Kingdom	311	7.72%	18.65%	0.00%	29.58%	32.48%	0.00%	7.07%	4.50%
Japan	986	0.00%	0.00%	8.11%	43.41%	30.22%	11.97%	3.55%	2.74%
Russia	986	0.00%	17.14%	17.14%	48.68%	14.10%	2.64%	0.00%	0.30%
Canada	650	1.85%	15.54%	57.69%	10.15%	12.15%	0.00%	0.00%	2.62%
France	545	3.12%	76.33%	11.38%	2.94%	3.12%	0.00%	0.00%	3.12%
Brazil	526	0.00%	2.85%	69.58%	8.75%	0.00%	3.80%	10.84%	4.18%
Paraguay	57	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Appendix B

This chart shows the amount of energy used by the 11 most popular electric vehicles. From this, the Ford Focus EV measured closest to the average, because of this, the Ford Focus Petrol model was used as the baseline evaluator for a gas powered car (EPRG, 2016)

Vehicle	kWh/100 km
Nisan Leaf BEV	21.0
Chevrolet Volt PHV	17.0
Toyota Prius PHV	18.0
BMW i3	13.5
Ford Focus EV	19.6
Tesla Model S	22.5
Tesla Model X	23.2
Toyota Rav 4	25.2
Honda Fit EV	18.1
Kia Soul EV	18.3
Mercedes Benz B Class EV	20.5
Average:	19.7

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