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Bryan R. Therrien

Worcester Polytechnic Institute

Deborah Kalambayi Njilabu

Worcester Polytechnic Institute

Jeremy Nathan Wiles

Worcester Polytechnic Institute

Peter F. Donaldson

Worcester Polytechnic Institute

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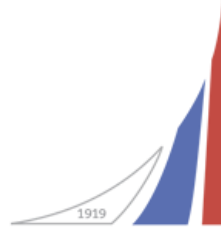
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Transforming Transportation:

Feasibility Study of Alternative Fuels in Moscow



WPI



FINANCIAL
UNIVERSITY
UNDER THE GOVERNMENT OF THE RUSSIAN FEDERATION

Submitted by:

Peter Donaldson
Deborah Kalamбайi
Ann Khakimova
Mark Polupudnov
Artyom Proskurin
Bryan Therrien
Max Usoltsev
Jeremy Wiles

Submitted to:

On-Site Liaison: Alexander Ilyinsky, Dean of International Finance
Department of the Financial University under the Government of the Russian Federation

Project Advisor: Svetlana Nikitina, WPI Professor

Transforming Transportation: Feasibility Study of Alternative Fuels in Moscow

An Interactive Qualifying Project
Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfilment of the requirements for the
Degree of Bachelor of Science

By

Peter Donaldson
Deborah Kalambayi
Ann Khakimova
Mark Polupudnov
Artyom Proskurin
Bryan Therrien
Max Usoltsev
Jeremy Wiles

Date Submitted: 11 October 2017

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Abstract

Moscow has fallen behind the world's push for alternative fuel development, due to a nearly ubiquitous use of gasoline vehicles. Our project seeks to determine the most economically feasible alternative fuel for Moscow's present and future vehicle economy. To accomplish this goal we conducted a life-cycle cost analysis on three vehicles selected to represent the Moscow consumer's buying preferences. We concluded that, at present, electric vehicles are non-viable in Moscow, while natural gas powered vehicles are practical, economical, sustainable, and take advantage of both the existing infrastructure and Russia's enormous natural gas reserves.

Executive Summary



Alternative Fuels In Moscow

Our project seeks to determine the most economically feasible alternative fuel for Moscow's present and future vehicle economy. To accomplish this goal we conducted a life-cycle cost analysis on three vehicles selected to represent the Moscow consumer's buying preferences. We concluded that, at present, electric vehicles are non-viable in Moscow, while natural gas powered vehicles are practical, economical, sustainable, and take advantage of both the existing infrastructure and Russia's enormous natural gas reserves.



Life Cycle Cost Analysis

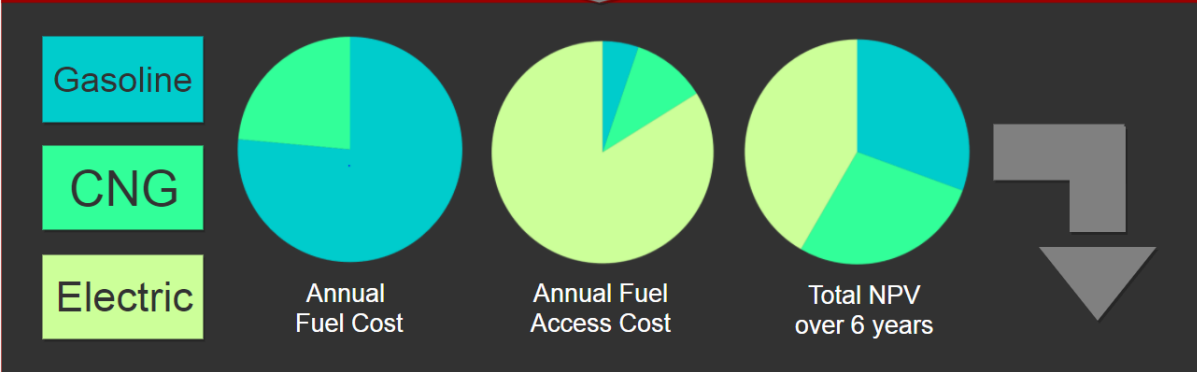
- Determine vehicles for three fuel types
- Conduct research on costs of ownership
- Develop calculations for yearly costs
- Evaluate NPV of vehicles over 6 years




Identify Costs

- Fuel price and inflation regression calculations
- Maintenance and service forecasting
- Convenience and fuel access cost prediction
- Net present value summation and analysis

RESULTS and FINDINGS





Recommendations

CNG vehicles are the most economically viable across our study period. The marginally higher initial cost makes converting a gasoline vehicle to operate on CNG both feasible and sensible. Electric vehicles are not currently efficient enough economically to justify large-scale usage in Moscow. In order for electric vehicles to become widespread, initial costs must be reduced through government incentives, and charging infrastructure needs to be expanded.

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- Professor Ilyinsky, Dean of the Faculty of International Finance for making this project possible and for allowing a cohesive collaboration between WPI students and students from his Faculty
- The Worcester Polytechnic Institute and the Financial University under the Government of the Russian Federation for making this collaboration possible

Authorship

Peter Donaldson

Contributed to the writing and editing of the project; performing the LCC analysis; writing the interview protocols and making the executive summary poster

Deborah Kalambayi

Contributed to the writing and editing of the project

Ann Khakimova

Contributed in identifying mechanics and conducting interviews

Mark Polupudnov

Contributed in performing the LCC analysis

Artyom Proskurin

Conducted interviews and translated them into English

Bryan Therrien

Contributed to the writing and editing of the project; in performing the LCC analysis and creating the executive summary poster design

Max Usoltsev

Contributed in performing the LCC Analysis

Jeremy Wiles

Contributed to the writing and editing of the project; performing the LCC analysis; writing interview protocols

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Chapter One: Introduction

Transportation is a fundamental pillar of modern society (Mathew, 2014). The ability to safely transport individuals and goods from one place to another forms the backbone of many economies worldwide. Given the established importance of transportation for industrialized economies, the demand for sustainable, consistent, and efficient fuel sources becomes abundantly clear. A country that optimizes its transportation by using commonly available and cost-efficient fuels can experience significant improvements in economic productivity and environmental cleanliness. In 2017, countries worldwide are striving towards this goal by promoting and committing to the widespread usage of fully electric vehicles (EVs) (EIA, 2017). Despite tangible progress made across the globe, the Russian Federation remains in a minority among developed countries that have yet to make major steps towards EV adoption. In this economic analysis, we attempted to determine whether Russian consumers can benefit economically from converting directly to electric vehicles, or if natural gas powered vehicles could serve as an economically advantageous intermediary step between gasoline-powered and electric cars.

Our sponsor, The Financial University Under the Government of the Russian Federation, expressed interest in determining the economic feasibility of alternative fuels for the average consumer, and for Moscow as a whole. With this project complete, we hope to present a comprehensive comparative analysis of the net costs of owning and operating vehicles of varying fuel types over a six-year period in Moscow. This will allow us to establish the economic feasibility of each fuel type on a large scale, as well as offer constructive suggestions on best practices for the future in regards to governmental actions and environmental policy. Our conclusions are designed to aid consumers in making economically sensible purchase decisions, and to propose legislative decisions to city authorities responsible for transportation infrastructure.

In order to achieve these goals, we imposed the following objectives: 1) Identify the technical requirements of natural gas and electricity as fuels for transportation, and the infrastructure required to support them, 2) analyze market data in Moscow to identify appropriate test vehicles to examine in a life-cycle cost analysis (LCC), 3) Estimate future changes in fuel prices and availability using regression analysis, and 4) Determine the economic effects and feasibility of alternative fuels within the Moscow economy through the eyes of the average Moscow vehicle consumer. Ultimately, our research tries to answer whether a large scale transition to natural gas powered or electric vehicles is a sensible choice for Moscow residents or whether Russia's current dependence on gasoline should continue until electric vehicles prove feasible.

Chapter Two: Background

This chapter describes the properties and uses of alternative fuels in personal transportation. The section will focus on natural gas and electricity in order to establish a backdrop for further economic analysis of these fuels in Moscow's vehicle market. We

begin with a discussion of the technical characteristics of natural gas and electricity, and their respective environmental impacts when used in personal vehicles. We then cover the prominence of alternative fuels in other countries around the world. Finally, we discuss Russia’s natural resources and how this affects the Russian Federation’s transportation sector.

2.1.0 Natural Gas as a Fuel

Natural gas is one of the safest hydrocarbon fuels available (NGV Global, 2017). The average person can detect the smell of odorized natural gas at a concentration in air of 0.3 percent, which is approximately 16 times lower than the threshold for combustion. Natural gas is also less dense than air, and will readily dissipate into the atmosphere, minimizing the risk of fire hazards and accumulation at ground level. This is especially important for crash safety, and a safe refueling process. There are two types of compressed natural gas (CNG) refueling stations: time-fill, and fast-fill (United States Department of Energy, 2016). Time-fill stations are simpler and cheaper but can take several hours to refuel a vehicle. Fast-fill CNG stations are slightly more complex and expensive, but are able to refuel vehicles in a matter of minutes. In terms of the cost of refueling, CNG prices are generally lower and more stable than petrol and diesel per Gasoline Gallon Equivalent (GGE), as can be seen in Figure 2-1 below. While these values are for the United States, the relative costs

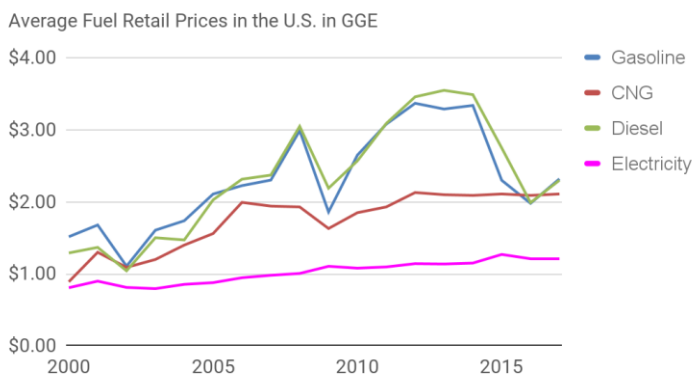


Figure 2-1: Fuel Prices in the US

of these fuels to one another is approximately the same in Russia (Gazprom, 2016). In order to benefit from these low, stable prices, gasoline vehicles can be converted to run on CNG. However, converting existing gasoline-powered personal vehicles to operate on natural gas introduces upfront cost. In Moscow, a complete conversion system can be purchased from a roadside shop and registered for less than \$1,000 USD

(Kramer, 2013; Plankin, 2017, see appendix B). Compressed natural gas vehicles are equivalent to petroleum vehicles in all areas except driving range, as CNG is slightly less energy dense than gasoline (U.S. Department of Energy, 2016). Natural gas is universally transportation-friendly. Natural gas pipelines are 90 percent efficient in the delivery of fuel, similar to electricity, which is about 92 percent efficient when delivered through power grids (ABB, 2007; Inside Energy, 2015). This high efficiency improves the economic feasibility of long distance energy transportation. Natural gas can also be converted into electrical energy through a combined cycle plant, which is able to convert natural gas to electricity at up to 60 percent efficiency, compared to the 33 percent efficiency of coal power stations (Power Engineering International, 2010; World Coal Association, 2017; Natgas, 2013).

2.1.1 Electricity as a Fuel

One of the most recent innovations in personal transportation has been the introduction of electric motors for vehicles (Idaho National Laboratory, 2017). These motors have few moving parts, high efficiency, low operating costs, and (indirectly) produce less emissions. In terms of vehicles, electric motors are currently three times more energy-efficient than gasoline engines (United States Department of Energy, 2017). EVs have varying ranges, and can travel anywhere between 150 and 800 kilometers on a single charge (depending on battery size), making certain models competitive with almost all internal combustion engines. EV charging operates on a tiered level system (Plug in America, 2011). There are three levels, with level one being the simplest and cheapest, and level three being the most complex and expensive. Level one charging involves plugging the electric vehicle directly into a standard wall outlet. This is the most cost-effective method, as most EVs come with a free charging cable and can be charged at home, overnight. A typical EV would take between 5-30 hours to fully charge depending on battery size, and the wall outlet voltage (120V vs. 220V). For those who do deplete their battery daily, level one charging will not be able to fully charge their vehicle overnight. Level two charging operates at 200-240V, and can charge an EV in 1-8 hours. Due to increased complexity, level two chargers cost about \$2000. Level three charging is also known as “Supercharging” or “Fast charging.” Most EV batteries can be fully charged in as little as 20-60 minutes. Level three stations use high voltage (480V), and require special, dedicated power lines. These can cost up to \$100,000. This high cost, combined with the special power requirements limit supercharger installation to commercial or public areas. Most supercharging is also only feasible for countries with developed economies.

2.2 Environmental Impact of Alternative Fuels

Natural gas vehicles are cleaner than their gasoline counterparts. As seen in Table 2-1 below, the three gaseous byproducts of combustion are significantly higher for petrol than for CNG. Electric engines do not produce any emissions themselves, however, the methods utilized to generate power for these engines typically do. An EV’s electrical power, generated by burning coal in a thermoelectric plant, produces more carbon emissions than driving a gasoline-powered car (Biello, 2016). However, burning other fossil fuels like compressed natural gas and oil produces less emissions (Union of Concerned Scientists,

2016). In a modern natural gas power plant, gas combusted within a generator gives off less than 50 percent the carbon dioxide of a typical coal-fired plant. Alternatively, hydroelectric plants, wind farms, and solar farms are all low-impact methods for producing electricity without the emissions output of fossil fuels.

Emissions (g/mi)	NOx	CO2	CO
Petrol	0.78	666.85	5.83
CNG	0.54	563.54	1.99

Table 2-1: Emissions Output Table

2.3 Alternative Fuels around the Globe

China has the world's largest natural gas vehicle fleet (4 million vehicles), which accounts for 17.8 percent of the global NGV total (Hao, Li, Liu & Zhao, 2016). In 2014, the country had more than 6,500 natural gas refueling stations, representing 24.4 percent of the global total. About 80 percent of Chinese CNG passenger vehicles (taxis and private passenger vehicles) have been converted from gasoline. Conversion from gasoline to CNG powered vehicles is preferred over purchase of a manufactured CNG vehicle because of the reduced cost. In Armenia, 56 Percent of vehicles are powered by CNG. This is the highest percentage of any country in the world (NGV Global, 2017). This immense popularity in CNG-powered vehicles can be attributed to the fact that the fuel is 60 percent cheaper by energy capacity, than gasoline (EBC, 2012). The country has 556 CNG fueling stations, which equates to roughly one station every 53 square kilometers, or one station every 7.2 linear kilometers. China also currently has the largest electric vehicle market in the

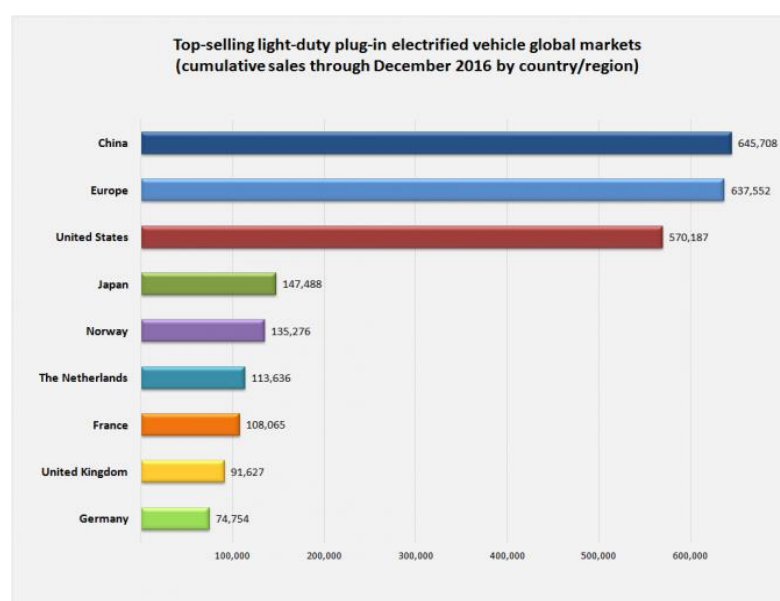


Figure 2-2: Top Selling EVs

world, accounting for 40 percent of the world's total in 2016 (IEA, 2017). In the same year, a total of 100,000 electric charging stations were constructed, bringing the total count to 150,000 and making them the world leader (China Daily, 2017). In major cities, a charging station can be found at a radius of under 5 km. Government incentives include subsidies of up to 30 percent the initial cost of the vehicle, monetary grants to companies that build charging stations, exemption on annual vehicle taxes, free charging at certain locations, and free or reduced parking fees for electric vehicle owners (Truman, 2015). The country has also recently announced a plan to ban the import and sale of petrol and diesel cars, with the aim to promote the expansion of the electric vehicle market (LA Times, 2017).

Norway has the highest number of electric vehicles per capita in the world (Milne, 2017). This enormous technological feat can be attributed to government incentives, which include exemption from import taxes, immunity to tolls, and guaranteed free parking (EV Norway, 2017). According to recent surveys, the main reason for the growth of alternative fuel vehicles is the economic benefits derived from their purchase and extended use (Haugneland, 2016).

2.4 Alternative Fuel Usage in Russia

Russia has the world's largest natural gas reserves and the second largest production output (CIA, 2017). 53 percent of Russia's annual energy is generated using natural gas (EIS, 2013). There are currently over 250 CNG fueling stations and 145,000 CNG vehicles in Russia (Gazprom, 2016). Gazprom, Russia's leading CNG production and

distribution company, plans to double the number of CNG fueling stations in Russia over the next four years. Gazprom officially quotes conversions from gasoline engines to CNG engines at 90,000 rubles (approximately U.S. \$1,500) and fuel costs at 30 percent lower than gasoline. At these costs, the return on investment would begin after just 30,000 kilometers of travel. While complex fast-fill refuelling stations may be the most convenient (in terms of fueling time), they may not be a cost-effective solution in sparsely populated areas due to their high initial cost of approximately one to four million dollars (United States Department of Energy, 2016). This drastic, up-front cost is unlikely to be justified if the station only services a small number of people. Small, time-fill stations, with their slower, less power-hungry refill technology, are significantly cheaper and simpler when compared to their fast-fill counterparts. This makes time-fill stations easier to install in remote locations, like north-eastern Russia. An inexpensive time-fill station costs as little as \$10,000. Companies such as Gazprom have taken initiatives to increase the use of CNG as fuel for vehicles with some success, but the largest factor limiting usage of CNG vehicles is the lack of infrastructure to fuel these vehicles (Gazprom, 2016). 66 percent of the electricity generated in Russia is generated in plants that burn fossil fuels, 18 percent of Russian electricity is generated by hydropower, and 16 percent comes from nuclear plants (EIA, 2016). The cost of electricity in Russia is \$0.11/kWh, which is similar to that of the US (\$0.12/kWh and slightly more expensive than China or India (\$0.08/kWh) (OVO Energy, 2017). By the end of July of 2016, there were only 722 electric vehicles in Russia (Auto Consulting, 2016). The most immediate barriers for the Russian electric vehicle market is the limited availability of affordable EVs, and the perceived effect of weather on the range of the vehicles. The batteries that power electric vehicles have an energy-storing chemical composition whose capacity is reduced about 30 percent by especially cold weather (EERE, 2017). Other countries, such as Norway and the US ignore this factor as its effects are minor, and benefit from flourishing EV markets. The temperatures of a Moscow winter are similar to these countries, which suggests that it is not a major limiting factor. The limited availability of electric vehicles and infrastructure constraints are the more prominent limiting factors in Russia. Nonetheless, there is a vision on part of the government to increase the usage of electric vehicles among citizens. The country's leader, President Vladimir Putin, has signed a document that states that the government intends to prepare the Russian automobile industry for the domestic production of electric vehicles by the year 2025, following "the world trends in the transition to mass production of electric vehicles" (The President of Russia, 2016).

Chapter Three: Methodology

The goal of this project was to determine whether Russian consumers could benefit economically from converting directly to electric vehicles, or if other alternative fuels could serve as economically superior intermediary steps between gasoline-powered and electric cars. To achieve this goal we developed the following methods, which include traditional database and archival research as well as formal and informal interviews.

3.1 Market Research

We conducted a life-cycle cost analysis to identify the total costs associated with vehicles of various fuel types (gasoline, CNG and Electric) over a designated period of time. Conducting market research on Moscow's vehicle economy helped us determine the most demanded vehicles' features, technical specifications and price points. All vehicles identified were gasoline-powered, as this is the most prominent fuel type in Russia by a large margin. We then compared the five most common vehicles in terms of cost, seating, power, range, and fuel economy. We averaged these parameters to select one car that most closely fits the market preferences. This vehicle was used as the baseline for our analysis. We then used these same values to determine the CNG and electric counterparts for our gasoline vehicle, establishing the set of vehicles for our comparison.

3.2 Identifying Costs

3.2.1 Identify Taxes/Incentives

In many countries, traffic, emissions, and other types of laws limit how vehicles are built, distributed, and operated. The Russian Federation is no exception. Our team carried out on-site research in order to determine these limitations. In order to do this we used resources provided by student teams and faculty at the Financial University to identify the costs and benefits incurred by the current laws and incentives. These resources included knowledgeable faculty, online databases, and literature available through the libraries and other departments of our sponsoring university. We also asked our student partners to determine whether there have been specific government initiatives (i.e. rebates on fuel, or taxation) implemented to subsidize the sale and adoption of alternatively fueled vehicles.

3.2.2 Identify service costs

To fully understand the maintenance costs associated with vehicles of alternative fuel types in Moscow, our team interviewed (refer to appendix C for interview protocol) multiple vehicle mechanics. This helped us to identify Moscow vehicle-owners' capacity to convert their own vehicles (or have their vehicles converted by a professional) to use CNG fuel, as well as the maintenance costs associated with each fuel type.

3.2.3 Identify and Project Fuel Prices

In order to accurately predict operating costs of the vehicles, we needed to estimate future fuel prices over the 6-year length of our study. With guidance from our Financial University colleagues, we used 10 years of fuel price data to create a linear regression model (See Appendix A).

3.2.4 Identify availability of fueling centers

In order to predict the "convenience cost" of refueling different vehicles, we determined how far the driver must travel to access the fuel. We did this by identifying the number of fueling stations of the various types (CNG, gasoline, and electricity) in the city of Moscow, and then conducted calculations in order to

determine the average distance and time a driver would travel in order to access the nearest station (for equation see Appendix E).

3.3 Conduct LCC Analysis

With the vehicle selection and cost identification processes complete, we used life-cycle equations to quantify consumer spending associated with the ownership and operation of each vehicle over a designated time period (equations found in Appendix F).

3.4 Conclusion

By implementing the above methods, we were able to effectively gather crucial information on the costs of alternatively fueled vehicles in Moscow. This data was used to achieve our goal of providing our sponsor with a comprehensive report on the feasibility of transitioning to CNG and electric vehicles. Our findings and predictions have the potential to prompt further research and promotion of alternative fuel vehicles in Moscow, as well as raise consumer awareness as to the costs and benefits of different fuel types.

Chapter Four: Results and Discussion

4.1 Life-Cycle Cost Analysis

A life-cycle cost analysis (LCC) is an economics tool used to determine the total cost of an object or action by summing all expenditures and losses associated with it over a period of time (US Legal, 2016). The purpose of our life-cycle cost analysis was to identify the most financially efficient fuel option for the average Moscow vehicle owner. We studied three cars operating on different fuels and compared their respective costs. The vehicles we selected for this study are the Hyundai Solaris (gasoline), the Hyundai Solaris (CNG converted), and the Nissan Leaf (electric). The Solaris was selected through a comparison of the top selling cars in Moscow. By comparing various parameters (power, fuel economy, price, engine size, and range), we were able to identify the vehicle most suited to the average vehicle consumer in Moscow. The Hyundai was above average in all our categories, and had a similar price to its competition. It was also the best-selling vehicle in Russia in 2016. The Leaf was selected from a small grouping of electric vehicles currently available in Russia. It was the most similar to the Solaris in terms of price and features. Our study was conducted using a timeframe of six years. This length was chosen due to concerns of compounding statistical inaccuracy in long term fuel price estimations as well as the length of a new vehicle's average ownership before resale (six years) (KBB, 2012). The discount rate for our analysis was based on the expected rate of inflation. The ministry of Finance has targeted an annual inflation rate of 5 percent for the next four years (through 2021) (Ministry of Economic Development of the Russian Federation, 2016). We assumed that this number would remain constant for the additional two years of the study. This is a projection, which is subject to change, but it served as our best estimate for future market trends. Using a discount rate allowed us to determine the costs in terms of net present value (NPV). Present value is a prediction of the value of future spending. Using the Official Calculator from the Russian Union of Motor Insurers website, we were able to predict the insurance costs of each individual vehicle over the length of the study. The

calculator generates the insurance cost using the buyer’s city of residence, engine power, vehicle class, and period of use for the vehicle (PCA, 2017). Although it is relatively easy to summarize the costs associated with purchasing, insuring, maintaining, and operating a vehicle, there are some more complicated costs that depend on the consumer’s actual usage of the vehicle. In order to quantify these more subjective costs, we developed the “Convenience Factor”. The “Convenience Factor” attempts to summate the cost of accessing various alternative fuel types for the average Moscow consumer by using average wages, refueling station distribution, and fuel costs (Refer to Appendix E for equation). In doing this we were able to place annual costs on the monetary inconvenience of accessing alternative fuels.

Fuel prices are notoriously unstable. In order to ensure the most accurate and consistent economic data, we chose regression analysis to predict the future costs of the fuels we would be analyzing (see Appendix A). This began by recovering the past annual prices for these fuels since the year 2008. Then, the slope was calculated from our earliest reference point to the current year in order to find the average rate of change across all data points. This is a best attempt at estimating accurate fuel prices given the uncertainties of foreign relations and economics for fuel states worldwide. We used these annual cost predictions as our fuel prices for electricity, natural gas, and gasoline over our six-year period for generating the price forecast.

4.2 Long Term Vehicle Cost Findings

The results of our life-cycle cost analysis reflect many of the trends we observed.

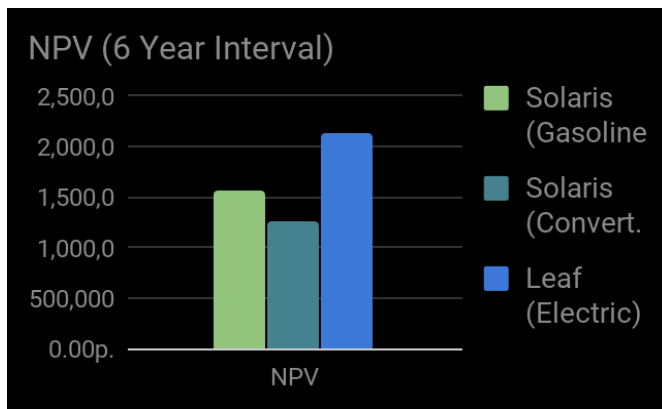


Figure 4-1: Net Present Value of Vehicles

Figure 4-1 shows the NPV (Net Present Value) of the selected vehicles over the six-year interval. All results are relatively contiguous, with the lowest NPV (Solaris CNG) coming in at 33 percent lower than the highest (Leaf). The Leaf generates the highest cost at 2,130,000 rubles, making it the least feasible option within the six-year study period. The Solaris has a NPV of approximately 560,000p lower than the Leaf. The converted Solaris has a lower NPV than the gasoline Solaris implying that converting a vehicle to CNG does increase its economic efficiency. Over a six-year interval, the results show that vehicles using CNG have a lower NPV than gasoline or electric cars.

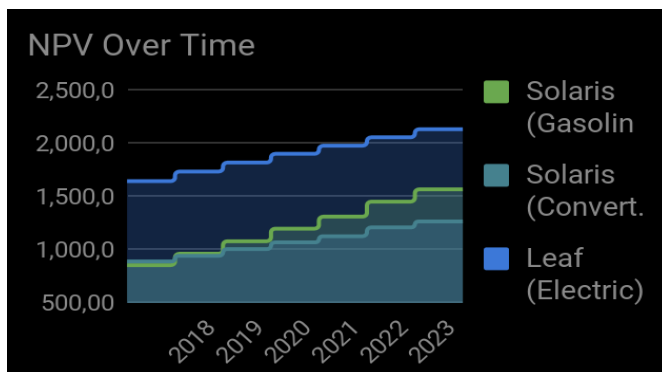


Figure 4-2: NPV of Vehicles (6 Years)

Figure 4-2 displays the change in NPV over time. The first NPV data point shows that the Solaris and Converted Solaris have very similar initial costs, with the Leaf significantly higher (55 percent higher than the next most

expensive car). However, the NPV measurements converge over time. Although the Leaf has the highest initial cost, its annual change in NPV (cost of ownership) is the lowest. Within six years its variance from the Solaris changes from 92 percent to only 33 percent. This is remarkable as it implies that the NPV value forecast for additional years would put the Leaf below the gasoline Solaris in terms of its NPV. The gap between the Leaf and converted Solaris vehicle also decreases, but at a much lower rate. This is caused, primarily, by the high convenience cost of accessing electric charging stations. The current trends show that the converted Solaris would have the lowest NPV by its end-of-life (6 years).

The converging NPVs of the vehicles over time is best explained by the fuel costs per year. As is shown in Figure 4-3, the Solaris has much higher annual fuel costs than the CNG alternative. The Leaf, which presents no fuel costs, is not included here. This graph reflects

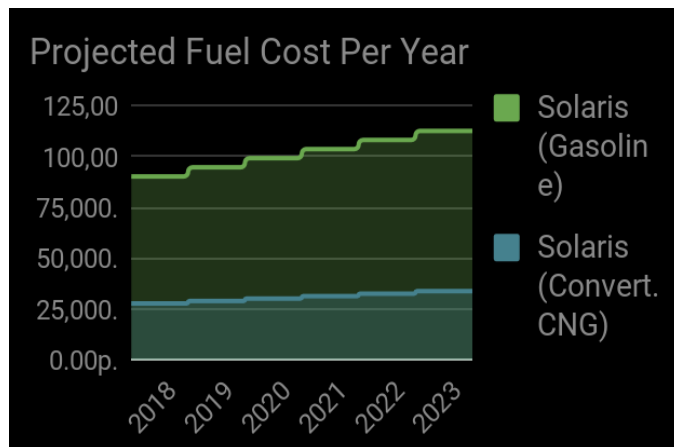


Figure 4-3: Fuel Cost Projections

the economic benefits of CNG as an alternative to oil. As the study continues, this inevitable cost of fuel will remain, raising the NPV of the gasoline choice at a much higher rate than the alternatives.

We can also look at Figure 4-4, which shows the difference between the initial cost and the NPV. It shows the total cost to own and operate the vehicle over the six year period. The gasoline Solaris has the highest operating cost, mainly due to the fuel costs as shown in Figure 4-3. The Leaf has no fuel costs but is still the second most expensive car to own, due to its significantly higher convenience cost (convenience cost comparison shown in Appendix H). The converted CNG Solaris has the lowest operating cost due to its significant advantages in fuel costs over the gasoline Solaris and in convenience cost over the Leaf.

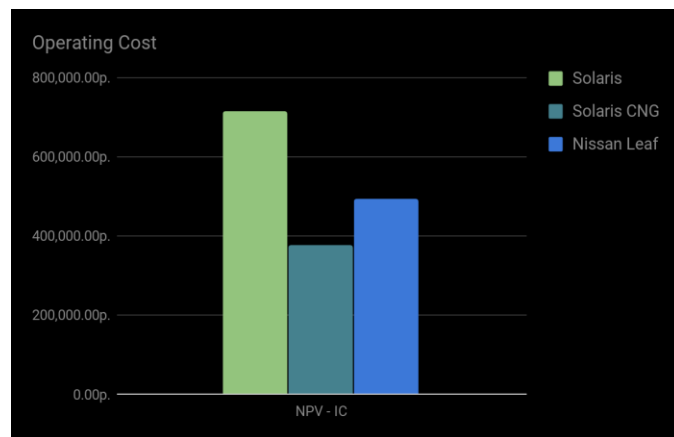


Figure 4-4: Operating Costs over 6 Years

Term Costs	Solaris	Solaris CNG	Leaf
Price	850,000.00p.	885,000.00p.	1,638,000.00p.
Fuel Cost	511,326.29p.	155,423.74p.	0.00p.
Maintenance	95,350.16p.	95,350.16p.	24,726.44p.
Insurance	50,163.06p.	50,163.06p.	48,533.77p.
Transport Tax	15,607.75p.	15,607.75p.	13,831.26p.
Convenience Cost	24,695.32p.	51,195.98p.	394,731.22p.
Intangible Costs	Costs without monetary values. Not part of economic analysis.		
Vehicle Safety	★★★★	★★★★	★★★★★
Emissions	Most Concern	Some Concern	Least Concern
Key	Largest	Median	Smallest

Table 4-1: Tangible and Intangible Costs

4.3 CNG Vehicles are Feasible

CNG vehicles are currently the best option financially for Moscow residents looking to purchase a vehicle. The high initial cost of electric cars, and the current lack of charging infrastructure, make electric vehicles non-viable in Moscow today. Converting vehicles that run on gasoline to use CNG has proven both cost-effective, and sensible in terms of maintenance. Our research proves that Moscow residents who already own a gasoline vehicle within this price range can benefit economically from the upfront conversion cost within just one year of purchase, thanks to reduced fuel prices.

4.4 Future Prospects for EVs in Moscow

Electric vehicles can still be competitive in Moscow if some structural conditions are met. Their stable, low operating costs, and minimal maintenance make them ideal for any consumer open to a higher initial cost and with access to a home outlet or nearby charging station. Unfortunately, due to street parking and minimal fast-charging infrastructure, the average consumer in Moscow is unable to access charging stations easily. The lack of

domestically manufactured EVs means consumers are paying import taxes and customs duties, adding even more burdens to the already substantial initial cost of an electric vehicle. An intermediary conversion to CNG vehicles is needed to help foster environmental and economic consciousness among consumers, and buy time for an EV infrastructure to establish itself.

4.5 Electricity is the Cheapest Fuel

Despite some of the shortcomings of EVs in Moscow today, electricity as a fuel is still in very good standing. Even when considering the price of home charging versus charging at a free station, the annual cost of electric vehicle power is exceptionally low. Electricity is also the cheapest in terms of environmental costs (Union of Concerned Scientists, 2016). Generating the electricity to power electric vehicles in Russia produces less emissions than CNG or gasoline vehicles (this reduction depends on what fuel sources are being used to produce the electricity, and changes regularly). This leaves electricity as the hands-down best fuel choice for consumers, limited only by infrastructure and vehicle availability. This poses the question of which methods are best for power generation. Our research indicates that the highest efficiency, and cleanest fossil-fuel powered thermoelectric plants are run on natural gas. Further engagement of Russia's enormous natural gas resources could lead to long term stability in electrical energy prices, efficient power generation, and overall low costs for future EV expansion.

Chapter Five: Recommendations

- **Convert to CNG as Interim Step:** Russia houses immense reserves of natural gas that are not currently utilized to their full potential. Compressed natural gas has also proven to be a safe, reliable, stable, and cost-effective fuel for personal vehicles. In lieu of this, we suggest promoting the sale of CNG vehicles or encouraging consumers to pay the reasonable upfront price of a CNG conversion. Our analysis shows that, at present, converted CNG vehicles are an exceptionally good value for the average consumer. Their reasonable initial cost is very quickly subsidized by incredibly low and stable fuel prices. There is sufficient CNG fueling infrastructure for CNG vehicles in Moscow, and the extra cost assumed by increased fill times is insignificant compared to the projected increase in prices of gasoline.
- **Offer Government Incentives:** Most countries with thriving EV markets (China, USA, Norway) owe their success in part or entirely to government incentives. However, neither the Moscow, nor Russian government has incentivized the adoption of electric vehicles. In order to rectify this deficit, we have a number of

proposed solutions. For example, a state-imposed emissions tax that scales based on quantity and quality of emissions would discourage the purchase of environmentally unconscious vehicles while generating revenue for the government. Electric vehicles, producing little to no emissions, would be exempt from this tax. This would make electric vehicles an economically and ecologically appealing choice for consumers, and would help to justify their higher price tag.

- **Start Domestic Production:** The predominant cause of high purchase costs for electric vehicles in Russia is the lack of local production. This means EVs are imported from European or Asian countries and resold at inflated prices. This serious hurdle for the EV industry in Moscow is caused by the inclusion of import taxes and custom duties on electric vehicle imports. Removing or dramatically reducing these taxes would bring the price of EVs closer to factory prices, making them more affordable and thus expanding the market. The other option would be for the government to encourage car-manufacturers to produce electric vehicles locally, instead of importing them, eliminating the import taxes entirely and in turn lowering prices. The government could also subsidize EV sales with tax rebates or cash-back offers, as this technique has proven very successful in countries such as Norway, China (mentioned in our background chapter), and the United States.
- **Develop Charging Infrastructure:** A major obstacle for the advancement of the EV industry in Moscow is the lack of charging infrastructure. We suggest that the government, or private corporations invest in the construction of electric charging stations, or super-chargers, in the Moscow region. This endeavor could be funded by aforementioned emissions taxes and would significantly reduce the convenience cost of charging, making EVs more appealing to Moscow car buyers. Although this solution comes at a high price, it would ultimately prove a wise financial investment, facilitating immense savings and ecological improvements across the transportation sector.

Chapter Six: Conclusion

Our data indicates that Moscow is not yet prepared to transition from gasoline to electric vehicles, but would benefit from converting to a more cost-effective, alternative fuel such as CNG as an interim step. High upfront costs, lack of fast-charging infrastructure, and an inability to charge from home, make the EV an extremely impractical choice for the average Moscow vehicle consumer. This, however, gives light to another option. Gasoline vehicles converted to CNG have proven to be efficient, practical, and accessible, while

providing a significant cost reduction for the consumer. Natural gas fueling infrastructure is currently well developed within Moscow, and suits the CNG fuel market well. As a result of our research, we can comfortably recommend the usage of converted CNG vehicles as an alternative to gasoline, at least within the near future. However, the end goal remains to convert to even more efficient and environmentally-friendly options. As the remainder of the modern world moves towards fully electric cars, it is essential that Moscow and the Russian Federation advance their EV infrastructure and availability. In 2017, there are only two factors impeding the economic viability of the electric car: purchase price, and charging options. Government action to bolster the number of charging stations and outlets in Moscow to just half of the current availability of gasoline stations would immediately make vehicles like the Nissan Leaf a more economically sensible choice. Also, government incentives, as seen implemented in the United States, China, and Norway, have immense potential for encouraging the sale and usage of EVs. The best available solution would be an imposition of emissions or purchase tax on high emission vehicles, the yield from which could be used to subsidize the purchase of electric vehicles and the development of charging infrastructure.

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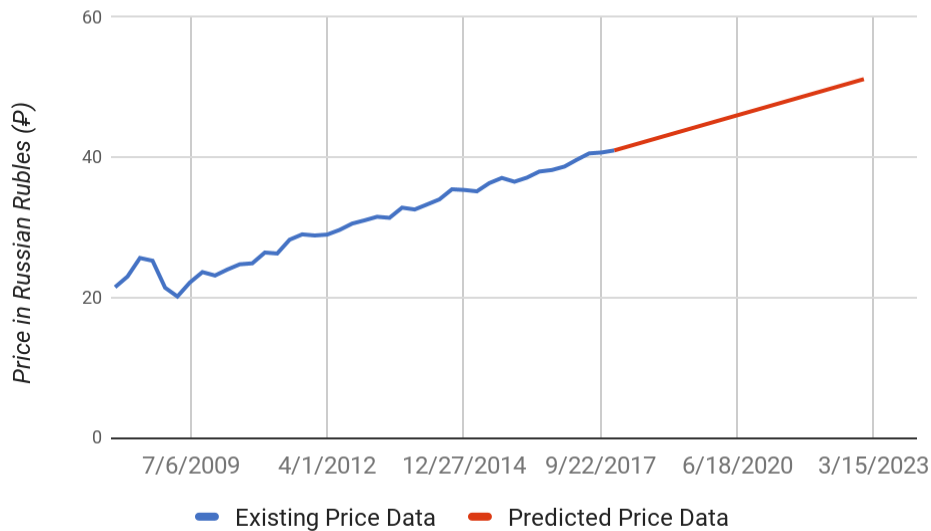
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Appendices:

Appendix A: Fuel Price Regression Analysis Gasoline -

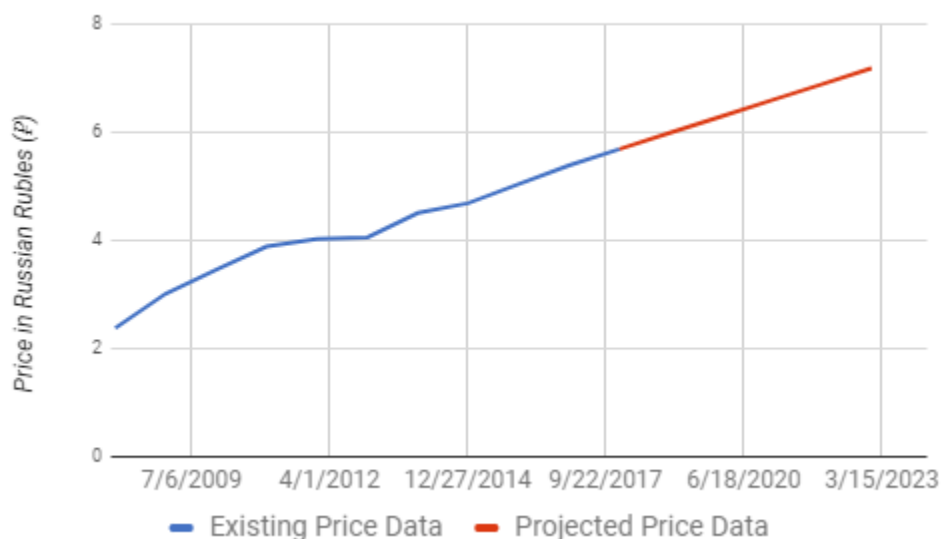
Dynamics of AI95 Gasoline Prices (Per Liter)



Conclusion							
AI95 Gasoline							
Regression statistics							
Multiple R	0,9805003848						
R Squared	0,9613810046						
Normalized R Squ	0,9603647152						
Standard Error	1,206717759						
Data Points	40						
Dispersion analysis							
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>F Value</i>		
Regression	1	1377,493536	1377,493536	945,9717374	0		
Balance	38	55,33437447	1,456167749				
Total	39	1432,82791					
	<i>Coefficients</i>	<i>Standard Deviat</i>	<i>T Statistics</i>	<i>P Value</i>	<i>(P-3nc</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Y Intersect	20,15488462	0,3888668411	51,82978461	0	19,36766485	20,94210438	
Variable X 1	0,5083714822	0,01652882949	30,75665355	0	0,4749106162	0,5418323481	

Electricity -

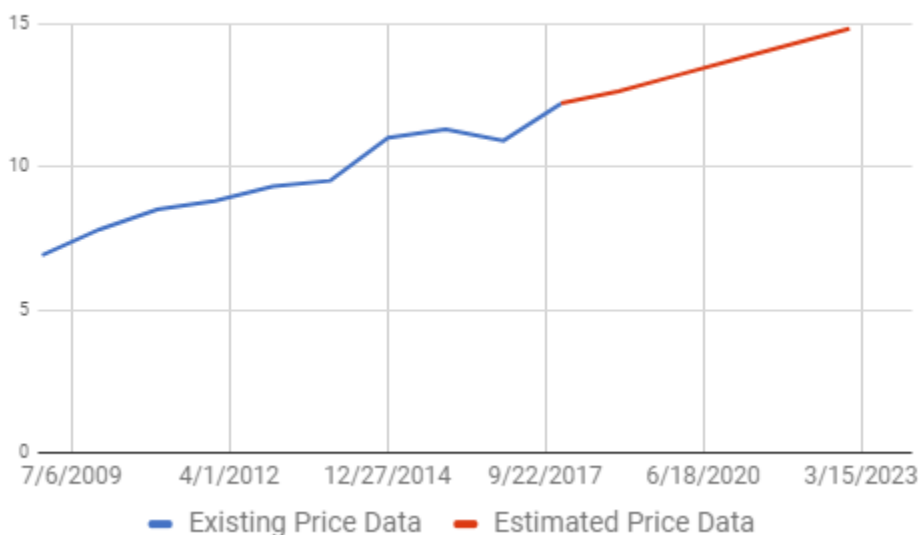
Dynamics of Electricity Price (Per KWh)



Conclusion							
Electricity							
Regression statistics							
Multiple R	0,9824829567						
R Squared	0,9652727601						
Normalized R Squ	0,9609318551						
Standard Error	0,1818824129						
Data Points	10						
Dispersion analysis							
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>F Value</i>		
Regression	1	7,356160303	7,356160303	222,36671	0,000000403332		
Balance	8	0,264649697	0,03308121212				
Total	9	7,62081					
	<i>Coefficients</i>	<i>Standard Deviat</i>	<i>T Statistics</i>	<i>P Value</i>	<i>(P-Знач</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Y Intercept	2,394666667	0,124249342	19,27307322	0,000000054486		2,10814717	2,681186163
Variable X 1	0,2986060606	0,02002459461	14,91196533	0,000000403332		0,2524292626	0,3447828586

CNG -

Dynamics of CNG Price (Per GGE)



Conclusion							
CNG							
<i>Regression statistics</i>							
Multiple R	0,9780066461						
R Squared	0,9564969998						
Normalized R Squared	0,9510591248						
Standard Error	0,3743883901						
Data Points	10						
<i>Dispersion analysis</i>							
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>F Value</i>		
Regression	1	24,65466667	24,65466667	175,8953627	0,000000996863		
Balance	8	1,121333333	0,1401666667				
Total	9	25,776					
	<i>Coefficients</i>	<i>Standard Deviation</i>	<i>T Statistics</i>	<i>P Value</i>	<i>(P-3σ)</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Y Intercept	6,613333333	0,2557559601	25,85798326	0,000000005368	6,023559032	7,203107635	
Variable X 1	0,5466666667	0,04121880516	13,26255491	0,000000996863	0,4516159315	0,6417174018	

Appendix B: CNG Expert Interview Results

Name: Планкин Алексей Анатольевич

Position: Chief Mechanic of МПАС car-care center

Date: 9/14/2017

What is the most popular car for Russian consumers in terms of class and price range?

- A popular segment of cars is about a million. I cannot say more. I'm a mechanic, not a salesman and this question is not quite for me.

What is the average consumer purchase? The question concerns the type of fuel, fuel economy and safety rating.

- Most often, we have cars running on gasoline, then natural gas-powered cars and then electric cars, which are very rare. Consumers most often drive gasoline vehicles.

Specialized mechanics shops work with gas equipment. We do not repair the fuel systems of machines running on alternative fuels. As for security ratings, I have not heard of it. Crash tests are not held in Russia.

Are there any initiatives to promote cars on natural gas in Russia? If so, which ones?

- This information, again, is available on the Internet. I heard something. Sometime in 2010, the company Gazprom launched an initiative to promote natural gas vehicles. But in my opinion, this entire topic has died out. I know that according to Moscow Time there was an order to make several parks: they converted or created car parks working on methane. It was also planned to take the platforms for these cars under them. They had to build and gasoline and gas refueling.

Taxes. When transferring to gas, the municipal authorities at that time supported this initiative at that time.

Long story short - there was a push, but no movement followed. There are several initiatives like this.

Have Russian consumers begun to adapt to electric cars and cars with natural gas? Are there hybrids? What is the public opinion about these types of fuel?

The Russian consumer has not yet begun to adapt to alternative types of fuel in the general sense. Hybrids sometimes pass by, but they are not too popular. The popularity of dual-fuel cars is among cars that have a large engine capacity and a great mileage in other words for those cars, for which it is profitable. The cost of installing gas equipment is about 30,000 rubles. If the mileage is small and the engine is small, i.e. the fuel consumption is small, in this case there is no sense to install an additional fuel system change the existing one.

Because after the payment for installing equipment, there will be expenses for its maintenance and illumination. There is also such a problem that you need to register this gas equipment. Those. if you want to put gas equipment on the car, you need to provide it to the traffic police, they will inspect it, give permission for re-equipment, there you go to the specialized office which says that gas equipment can be installed on this machine. You establish it, according to this conclusion. Then again you go to the GIBBD and you register the car. Simply put, it's still the same. It requires money and time. The scheme is confusing a bit for the average inhabitant so the people do not bother. Weighed all the pros and cons of the car.

How to convince Moscow citizen that he needs to transfer his private car to gas?

With money. As soon as he realizes that he will win in this money - he will put a gas system on his car. Benefits in the form of an economic class also.

What is the average price for the installation of gas equipment?

30000p. -35000p

What types of vehicles are best suited for conversion to gas?

Machines that have high fuel consumption and high mileage.

What is the best engine for conversion?

The larger the volume - the greater the benefit.

Are there any complications or risks arising from the use of cars on natural gas?

With a gas leak, it can explode from any statics. Membranes, gas rubber tubes require replacement in 3 years. There is a risk of tanning rubber tubes.

What problems do owners face after the conversion?

It is necessary to spend a lot of time registering a car in the traffic police. If you have not registered with the State Traffic Safety Inspectorate, there may be complications in the form of fines and even prohibitions on exploitation. In the traffic police will need to give 7 thousand. But people who use the services of companies that will do all this dreary work for them pay 30 thousand. As much as for re-equipment. This is one of the weighty reasons why people refuse to convert to gas.

What is the popularity of alternative fuel stations?

Relatively popular. Speaking about liquefied gas - with it there are no problems. And as for methane refueling - this is a big problem. They are very rare. Almost as rare as electric charging in Moscow. Their rarity is due to the fact that they are filled only with shuttle buses. Individuals will not want to switch to gas in these conditions.

What new infrastructure will be needed to move the city to gas? Do you need new pipelines?

Now liquefied gas is supplied by transporting the gas in tanks. Gas is produced at special enterprises, where it is liquefied. These are large enterprises, and they are removed from cities and people.

Natural gas is transported through pipelines. If the vehicles are converted to natural gas, then yes, new pipes will be needed. But in fact it is more realistic to switch to liquefied gas. Too much space will be occupied by cylinders in cars.

The US is currently moving from cars with diesel to fully electric cars. Do you think that cars on natural gas are an intermediate step for electric cars in Russia? If not, can Moscow support direct conversion to electric cars economically and socially?

Yes, I believe that gas fuel is an intermediate step. In Moscow, electric transport is of course necessary, but we have multi-apartment buildings in Moscow. We have no infrastructure for this transition so far. You can re-equip parking: put charging there. Moscow can support conversion with the help of tax incentives, put charging stations, create ecological zones where only electric vehicles can drive.

Have you noticed any growth trend in the popularity of cars with alternative fuels?

No, there is no trend.

Appendix C: Vehicle Mechanic Interview Protocol

- 1) What types of cars do you typically maintain here? Is it common to see electric vehicles/NGVs/hybrids/or converted NGVs?
- 2) Is service on NGVs/hybrids/converted NGVs/or electric vehicles more or less expensive than that of petrol vehicles? Which fuel types typically require the most maintenance?
- 3) Do your shops currently have the capacity to work on cars of alternative fuel types?
- 4) Within your trade, what are the popular opinions on alternative fuel vehicles? (NGVs, EVs, etc)
- 5) What costs are associated with converting a petrol vehicle to natural gas? Is this something your establishment is encouraging?
- 6) Which types of vehicles work best for NG conversions? (Class/size/economy/engine size/etc.)
- 7) Are there any safety concerns associated with these conversions?
- 8) What reasons do customers typically give when requesting a natural gas conversion?

Appendix D: LCC Assumptions

1. Analyzing period for LCC - from 2018 to 2023
2. Discount rate is taken as an expected average inflation rate for the years 2018-2021. It is assumed that the oil prices will be constant (around 40\$/barrel) and Russia will preserve its economic development and growth rates of GDP.
3. Expected future price for the fuels is derived from regression analysis.
4. Electric cars are powered on the special stations, electricity is provided for free there.
5. Convenience costs for vehicles is calculated by the estimating the least distance (average from the districts of Moscow) needed to travel in order to get to the refueling station.
6. Minus sign is omitted in every LCC table for convenience: every time we incur only costs, so the option with least NPV should be chosen.
7. It is expected that the driver will be able to use (i.e drive in comfort) the car within the 6 year period. Disposal or resale of the car is not assumed.
8. No tax exemptions are assumed, transport tax is assumed to be constant.
9. Insurance type - Compulsory insurance of driver responsibility ("OSAGO"), charge is the same for all years.
10. Maintenance costs are individually calculated for each option, based on the experience of previous usage of the car.
11. Assumed average salary in Moscow - 67899 RUB, assumed average speed - 51 km/hour, average duration of the working day- 9 hours, days worked within the month- 21 days

Appendix E: Methodology for LCC

Costs, taken into account	Explanation	Calculation formula	
Initial Cost	Initial cost of purchasing the car, including tax duty, if imported, and accessories	IPC +TDP+AS	
Fuel Cost	Cost of the fuel, consumed by the car within a year, assuming the average travel distance and average gasoline cost	Gasoline	FE*YD*PG
		Natural Gas Hybrid	FE*YD*n%*PGs+FE*YD*(100-n%)*PG
		Electric vehicle	FE*YD
		Electric Hybrid	FE*YD*PG
Convenience Cost	The cost of access to fuel, the time spent getting to fueling station, refueling, and returning multiplied by wages per year	AW*(TTF+(AS/ED))*(YD/R)	

Variables		Unit of measure
IPC	Initial purchase cost	RUB
TDP	Tax duty on import (purchase)	RUB
FE	Fuel economy	L/100KM
YD	Average distance travelled per year	KM
PG	Price of the gasoline per liter, average	RUB
PGs	Price of the gas per liter, average	RUB
AW	Average wage of worker	RUB/HR
TTF	Time to fuel vehicle	HR
AS	Average speed of travel	KM/HR
ED	Extra distance , needed to refuel, trip	KM
R	Range of vehicle	KM
n	Gas usage coefficient	%

Appendix F: LCC Vehicle Data

Gasoline							
Model of the car	Specification of the model	Fuel consumption	Range, km	Time to fill the car, h	Distance to the station		
Hyundai Solaris	1.6 liters (123 h.p.), Comfort 1,6 MT/AT	8.8 liters/100km on city roads.	488.6363636	0.17	5 km		
		0.088		0.17		5	
* In every table currency is rubles							
	2018 (1-st January)	2018	2019	2020	2021	2022	2023
Initial Costs	850,000.00p.	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.
Fuel Costs	0.00p.	90,178.00p.	94,666.00p.	99,154.00p.	103,620.00p.	108,086.00p.	112,552.00p.
Maintenance C	0.00p.	5,127.00p.	17,641.00p.	20,146.00p.	15,751.00p.	45,962.00p.	10,845.00p.
Insurance Cost	0.00p.	9,883.00p.	9,883.00p.	9,883.00p.	9,883.00p.	9,883.00p.	9,883.00p.
Transport Tax	0.00p.	3,075.00p.	3,075.00p.	3,075.00p.	3,075.00p.	3,075.00p.	3,075.00p.
Convenience C	0.00p.	4,865.41p.	4,865.41p.	4,865.41p.	4,865.41p.	4,865.41p.	4,865.41p.
Sum	850,000.00p.	113,128.41p.	130,130.41p.	137,123.41p.	137,194.41p.	171,871.41p.	141,220.41p.
PV	850,000.00p.	107,741.34p.	118,032.12p.	118,452.36p.	112,870.18p.	141,399.03p.	116,182.38p.
Cumulative PV	850,000.00p.	957,741.34p.	1,075,773.46p.	1,194,225.82p.	1,307,096.00p.	1,448,495.03p.	1,564,677.41p.
NPV 1,564,677.41p.							
Converted Hyundai Solaris, CNG							
Model of the car	Specification of the model	Fuel consumption	Range, km	Time to fill the car, h	Distance to the station		
Hyundai Solaris, converted to CNG	1.6 liters (123 h.p.), Comfort 1,6 MT/AT	8,8 liters/100km on city roads.	323	0.17	10 km		
		0.088		0.17		10	
	2018 (1-st January)	2018	2019	2020	2021	2022	2023
Initial Costs	850,000.00p.	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.
Fuel Costs	0.00p.	27,786.00p.	28,974.00p.	30,184.00p.	31,394.00p.	32,604.00p.	33,814.00p.
Maintenance C	35,000.00p.	5,127.00p.	17,641.00p.	20,146.00p.	15,751.00p.	45,962.00p.	10,845.00p.
Insurance Cost	0.00p.	9,883.00p.	9,883.00p.	9,883.00p.	9,883.00p.	9,883.00p.	9,883.00p.
Transport Tax	0.00p.	3,075.00p.	3,075.00p.	3,075.00p.	3,075.00p.	3,075.00p.	3,075.00p.
Convenience C	0.00p.	10,086.50p.	10,086.50p.	10,086.50p.	10,086.50p.	10,086.50p.	10,086.50p.
Sum	885,000.00p.	55,957.50p.	69,659.50p.	73,374.50p.	70,189.50p.	101,610.50p.	67,703.50p.
PV	885,000.00p.	53,292.86p.	63,183.22p.	63,383.65p.	57,745.08p.	83,595.21p.	55,699.84p.
Cumulative PV	885,000.00p.	938,292.86p.	1,001,476.08p.	1,064,859.74p.	1,122,604.81p.	1,206,200.03p.	1,261,899.87p.
NPV 1,261,899.87p.							
Electric							
Model of the car	Specification of the model	Fuel consumption	Range, km	Time to power the car, h	Distance to the station		
Nissan Leaf	Electro CVT (109 h.p./ 80 kWh)	-	137	0.50	35 km		
				0.50		35	
	2018 (1-st January)	2018	2019	2020	2021	2022	2023
Initial Costs	1,638,000.00p.	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.
Fuel Costs	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.	0.00p.
Maintenance C	3,000.00p.	5,500.00p.	3,000.00p.	5,500.00p.	3,000.00p.	5,500.00p.	3,000.00p.
Insurance Cost	0.00p.	9,562.00p.	9,562.00p.	9,562.00p.	9,562.00p.	9,562.00p.	9,562.00p.
Transport Tax	0.00p.	2,725.00p.	2,725.00p.	2,725.00p.	2,725.00p.	2,725.00p.	2,725.00p.
Convenience C	0.00p.	77,768.95p.	77,768.95p.	77,768.95p.	77,768.95p.	77,768.95p.	77,768.95p.
Sum	1,641,000.00p.	95,555.95p.	93,055.95p.	95,555.95p.	93,055.95p.	95,555.95p.	93,055.95p.
PV	1,641,000.00p.	91,005.66p.	84,404.49p.	82,544.82p.	76,557.36p.	78,614.11p.	76,557.36p.
0	1,641,000.00p.	1,732,005.66p.	1,816,410.15p.	1,898,954.97p.	1,975,512.33p.	2,054,126.44p.	2,130,683.80p.
NPV 2,130,683.80p.							
Type of the fuel	Selected cars						NPV
Gasoline	Solaris						1,564,677.41p.
Natural Gas, CNG	Solaris CNG						1,261,899.87p.
Electric	Nissan Leaf						2,130,683.80p.

Appendix G: Car Data

Gasoline: Hyundai Solaris



Producer: Hyundai
Price: 850,000 Rubles (With options)
Horsepower: 123 HP (92 kW)
Range: 489 km per 43 L Tank
Seats: 5
Fuel Economy: 8.8 L/100km
Description:

The Hyundai Solaris is one of the most popular cars in Moscow. Its high range, reasonable fuel economy, moderate price and attractive design make it an appealing choice for Moscow car buyers.

Electric: Nissan Leaf



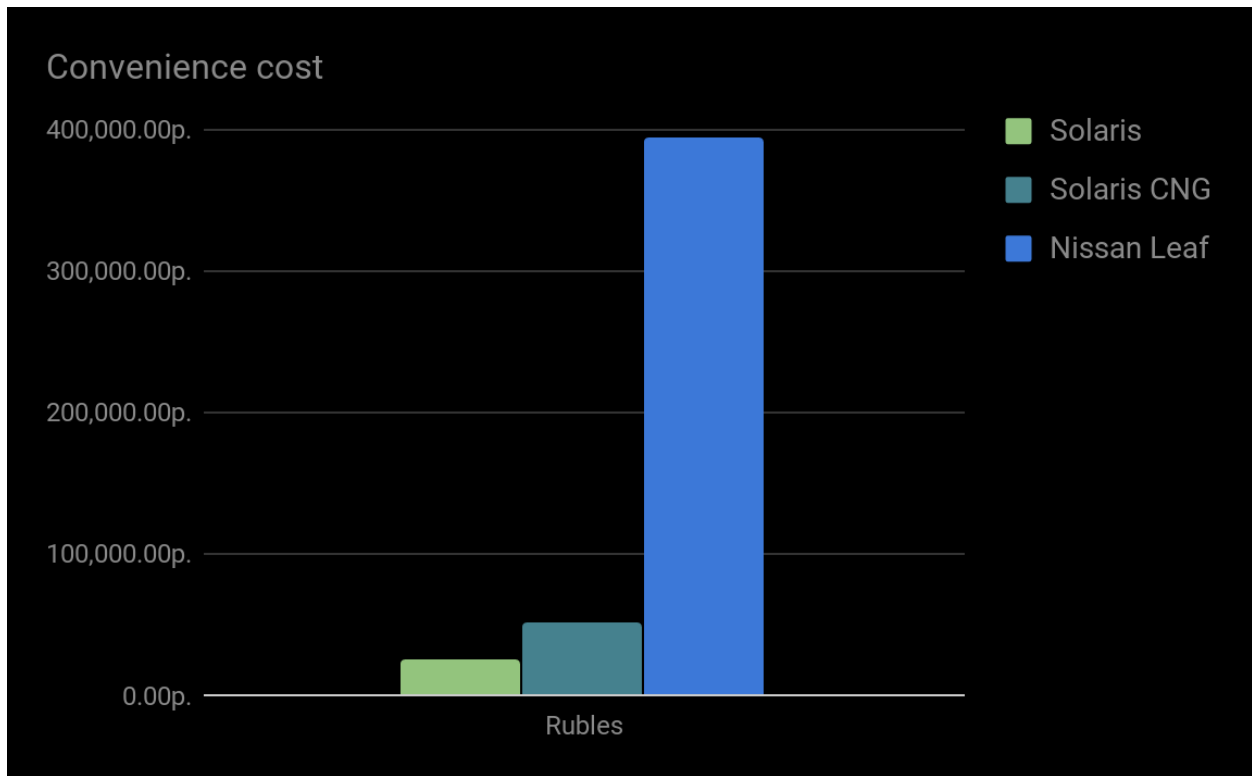
Producer: Nissan
Price: 1,638,258 Rubles (Base)
Horsepower: 109 HP
Range: 137 km
Seats: 5
Fuel Economy: 17.5 kWh/100km

Description:

The Nissan Leaf is one of the few electric vehicles currently available in Russia. It is the

vehicle that most closely matches the power and seating capacity of the other cars in this study. Its dramatically reduced range and higher price tag make it significantly less appealing to Russian consumers. However, it begins to make up for this shortcoming with superior fuel economy, and extremely low maintenance costs.

Appendix H: Convenience Cost Comparison Over 6 years in NPV



Convenience Cost (NPV)	2018	2019	2020	2021	2022	2023	Total Cost
Solaris (Gasoline)	4,633.72p.	4,413.07p.	4,202.92p.	4,002.78p.	3,812.18p.	3,630.64p.	24,695.32p.
Solaris (Convert. CNG)	9,606.19p.	9,148.76p.	8,713.10p.	8,298.19p.	7,903.04p.	7,526.70p.	51,195.98p.
Leaf (Electric)	74,065.66p.	70,538.73p.	67,179.74p.	63,980.70p.	60,934.00p.	58,032.39p.	394,731.22p.