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Comparing the environmental impacts of urban rail and other transportation systems on air quality, traffic reduction, and accident rates

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A B S T R A C T

Today, paying attention to environmental issues in urban development planning and actions can be an effective step in improving the state of the environment and improving the quality of life of citizens. The country's economic, social, cultural, and political conditions pose challenges for the future of the environment, and examining and identifying these challenges is essential for managing and improving the quality of the environment. Cities are both victims and culprits of environmental changes caused by human activities. Economic growth and industrial development have led to urbanization and an increase in the population of cities around the world. In recent years, environmental concerns such as the excessive use of natural resources, the destruction of wildlife habitats, the extinction of animal species, and various types of pollution have endangered the Earth as a human habitat. Sustainable transportation means finding efficient and easy ways to move people and vehicles with minimal energy consumption and environmental impact. Transportation has widespread negative impacts such as air pollution, noise pollution, heavy traffic, and increased accidents, and valuable urban land is allocated to streets and parking lots. In this article, the environmental impacts of urban rail compared to other transportation systems on air quality, traffic reduction, and accident rates are examined. This research examines and compares the positive and negative impacts of urban rail and other transportation systems from various environmental aspects. The results show that urban rail has positive impacts on the environment and public health by consuming less energy, producing fewer pollutants, and reducing traffic congestion. Also, the reduction of accidents caused by the use of urban railways compared to other public and private means of transportation is one of the important advantages of this transportation system. In contrast, the excessive use of cars and other unsustainable means of transportation have more negative effects on air quality and urban traffic. This article explains the solutions for improving and developing sustainable and efficient transportation systems in cities and points out the importance of using urban railways to preserve the environment and improve the quality of life of citizens.

1. Introduction

With the rapid growth of urbanization and population growth in metropolitan areas, public transportation systems have become one of the main pillars of sustainable urban development. These systems not only play a fundamental role in reducing traffic and facilitating the movement of citizens, but also have a significant impact on air quality, energy consumption and public health. In recent years, growing concerns about air pollution, climate change and dependence on fossil fuels have led to the consideration of electric public transportation as an efficient and

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sustainable solution. By using clean energy, these systems not only reduce greenhouse gas emissions, but also play an effective role in the formation of smart and green cities.

Considering the decline in fossil energy resources and its destructive effects on the environment, investment in electric public transportation is a strategic necessity. The increase in carbon dioxide concentration in the air of metropolitan cities has led to an increase in the number of days that vulnerable groups (such as the elderly and respiratory patients) have to stay at home, which, in addition to health and social challenges, also entails economic losses. Studies show that between 75 and 85 percent of air pollution in metropolitan cities is caused by motorized vehicles such as cars and motorcycles. Therefore, the development and use of electric buses and public transportation vehicles is recognized as one of the most efficient solutions to reduce air pollution, fuel consumption and urban costs. This article will examine the types of electric public transportation systems, their advantages, challenges and their role in the future of urban and intercity transportation.

Urban transportation systems play a crucial role in shaping the environmental landscape of cities. Among these systems, urban rail transit has emerged as a low-carbon alternative to traditional modes of transport, such as buses and private vehicles. This article explores the environmental impacts of urban rail compared to other transportation systems, focusing on air quality, traffic reduction, and accident rates.

Studies indicate that electric buses significantly reduce greenhouse gas emissions compared to diesel-powered alternatives. Research on urban transportation sustainability highlights the role of electrification in mitigating air pollution and lowering operational costs. Additionally, the total cost of ownership (TCO) for electric buses is becoming more competitive due to advancements in battery technology and charging infrastructure. (ESCAP,2023)

The rapid evolution of electric public transportation systems is driven by advancements in battery technology, charging infrastructure, smart grid integration, and autonomous transit solutions. These innovations are reshaping urban mobility, making electric transit more efficient, cost-effective, and environmentally friendly.

2. Approach

With the increasing use of personal and public transportation, dealing with environmental pollution caused by these vehicles is no longer a choice, but a necessity.

Iran is increasingly recognizing the importance of sustainable public transportation systems, particularly in urban areas where air pollution and traffic congestion are significant challenges. The transition to electric public transportation, especially through the implementation of battery electric buses (BEBs), is a crucial step towards a greener future.

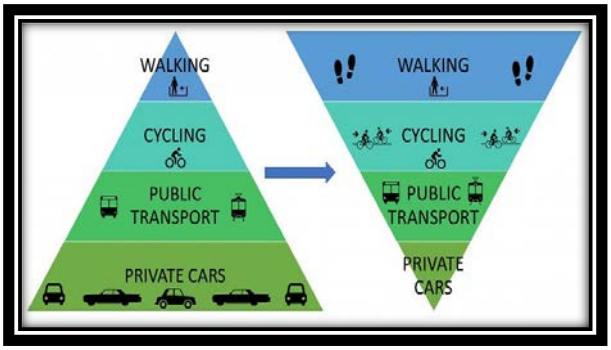

Figure 1- Comparison between different modes of transport

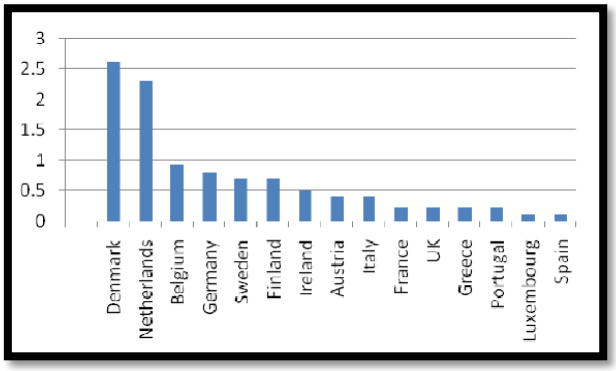

Figure 2- Cycling per person and day in kilometers (2000)

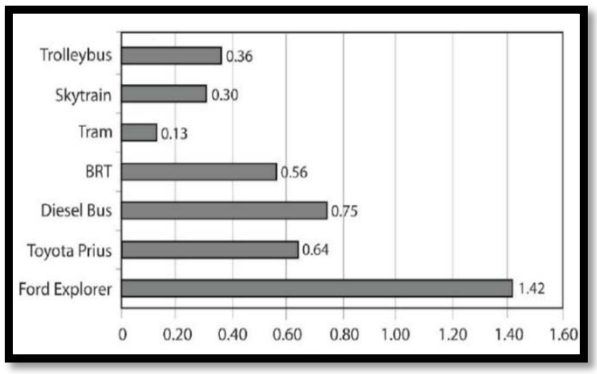

Figure 3- Energy Use (kWh/passenger-mile).

2.1. Current State of Electric Public Transportation in Iran

Tehran, the capital city, has been at the forefront of this transition. A study assessing the feasibility of overnight-charging electric buses in Tehran highlights the potential environmental benefits, including the elimination of carbon and nitrogen oxides, which are major pollutants from diesel buses. The study predicts a payback period of approximately seven years for the investment in electric buses, indicating a financially viable option for the city (Abbasi, 2022).

In addition to Tehran, other cities like Mashhad are also exploring electric public transport options. Mashhad's public transport system includes light rail transit (LRT) and bus rapid transit (BRT), but there is a need for redesigning these systems to enhance accessibility and sustainability (Mehr,2016).

2.1.1. Comparing the global perspective of countries around the world and Iran in the field of electrification of public transportation:

China, a global leader in electric public transport, has deployed thousands of electric buses in its major cities, such as Beijing and Shanghai. The results: significant reductions in air pollution and savings in fossil fuel consumption. These projects have also created new jobs in the production and maintenance of electric buses. Lesson learned: The importance of government support and large investments in charging infrastructure and electric bus production.

Japan, with a focus on new technologies, has invested heavily in the development of electric and hydrogen buses. The government has provided incentives for the development of charging infrastructure and the production of advanced batteries. South Korea is one of the leading countries in the development of electric public transport. Cities such as Seoul have extensive plans to replace diesel buses with electric models. The country has also invested in the production of advanced batteries and the development of charging infrastructure. India has invested heavily in the development of electric buses, driven by its large population and the need for sustainable transportation. The Indian government has provided incentives for domestic battery production and the development of charging infrastructure.

European countries such as Germany, France, and the Netherlands have invested heavily in developing electric bus fleets. The European Union has enacted strict policies to reduce greenhouse gas emissions and provided incentives for the use of electric vehicles. London is one of the cities that has widely used electric buses, and Spain is also developing fast-charging infrastructure for public transport. The Netherlands is a leader in green transport, with an extensive network of electric buses and zero-emission trains. More than 27% of Dutch city buses are electric, and this trend is increasing. Stockholm and Gothenburg use 100% renewable energy for public transport and are testing new solutions to develop sustainable transport. Australia has also moved towards electrification of public transport. Cities like Sydney and Melbourne have plans to replace diesel buses with electric models, and the government has offered incentives to develop charging infrastructure.

Some U.S. cities, such as Los Angeles and San Francisco, have implemented electric car sharing systems. Results: Reduced private car ownership, resulting in reduced traffic and air pollution. These projects have also increased public transportation use and reduced costs associated with private cars. Lesson learned: The importance of incentive programs for shared electric cars and the need to create adequate charging infrastructure. In Latin America, countries such as Mexico and Brazil have also moved toward electrifying public transportation. Mexico is expanding its electric bus fleet in major cities, while Brazil is looking to use renewable energy to power its public transportation.

Iran’s commitment to electrification is promising, with plans to expand its electric bus fleet in major cities and develop domestic manufacturing capabilities. Iran can also take inspiration from these global leaders while designing solutions tailored to its unique circumstances.

2.1.2. Air Quality and Urban Rail Systems

Rail systems significantly reduce greenhouse gas emissions: Urban rail systems typically emit 30 to 50 percent fewer pollutants than road vehicles, making them a more sustainable option.

Significant reduction in pollutants: Analysis shows that implementing rail systems contributes to significant reductions in particulate matter.

Improved health in cities: Case studies show that cities with improved rail systems experience long-term health benefits attributed to cleaner air and reduced exposure to harmful gases.

2.1.3. Comparison of pollutant gas production in metro and suburban trains

Table 1- Vehicle emissions and their costs in 1400

Pollutants	CO2	CO	NOx	Total
Gas produced per Liter of fuel (kg)	2.7	0.363	0.032	3.095
Gas produced per kilowatt hour of thermal power plant production (kg)	0.6812	0.004	0.0024	0.684
Cost per kilogram of polluting gases (rials)	1600	30000	96000	-
Cost of polluting gases per Liter of fuel (rials)	4320	10890	3072	18282
Cost of polluting gases per kilowatt-hour of thermal power plant production (rials)	1089.92	12	230.4	1332.32
Cost of polluting gases per kilowatt-hour of thermal power plant production (rials)	3205	8079	2279	13563
Cost of metro pollutant gases per passenger on the Parand route (rials)	2433	27	514	2974

The cost of producing polluting gases per Liter of fuel is about 18,282 rials and per kilowatt-hour of production in power plants is 1,332 rials. Also, the cost of polluting gases for the government in 1400 per passenger on the suburban train is about 13,563 rials and for the metro on the same route is 2,974 rials, which indicates that the metro performs better than the train.

2.2. Reducing traffic via urban trains:

Urban rail systems are a significant alternative to car travel and help reduce congestion in densely populated areas. Traffic Flow Analysis: Statistical evaluation shows significant improvements in traffic flow after the implementation of rail systems, highlighting their effectiveness. Urban Rail Integration: The role of urban rail in urban planning is crucial, ensuring that public transport works in harmony with other modes of transport. Economic Benefits: Reducing traffic congestion has a positive impact on the local economy, increasing business opportunities and improving community well-being.

2.3. Comparing safety and accident risk

The risk of a road accident is approximately 54 times higher than that of rail travel. This indicates the high safety of rail transport systems, which will also have an impact on the health of society in the long term.

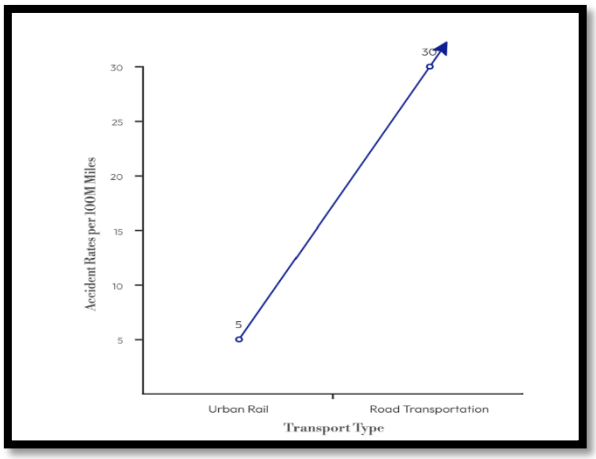

Figure 4-Safety comparison: rail vs. road

3. New green transportation methods

1. Electric Vehicles (EV): Electric cars, motorcycles and trucks that use renewable energy to minimize emissions

2. Cycling and electric bicycles: Using bicycles as one of the cleanest methods of transportation and electric bicycles that have higher speeds and can be very suitable for short distances

3. Clean public transportation systems: Electric buses and high-speed trains as effective

solutions to reduce the use of private cars and increase efficiency in passenger transportation

4. Smart traffic management: Using advanced technologies to optimize routes and reduce traffic, which helps improve traffic congestion and reduce fuel consumption

5. Carpooling system: Shared use of cars instead of individual trips, which can have a great impact on reducing traffic and emissions.

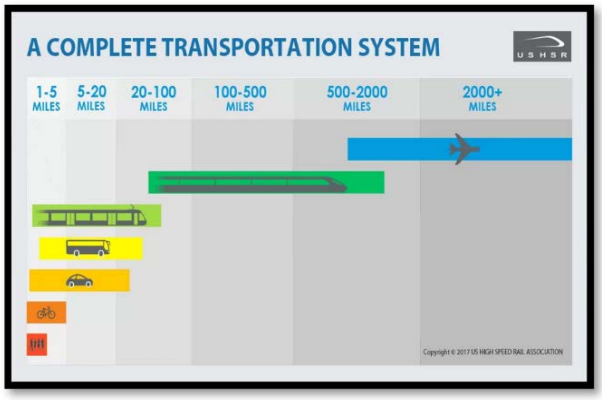

Figure 5-Comparing the coverage of different travel distances

Figure 6-Transport energy efficiency

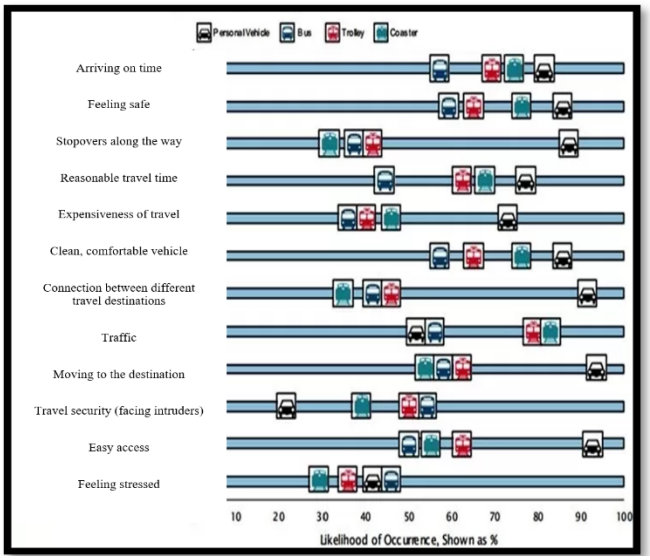

Figure 7-Comparison of different transportation methods based on type of function

Qualitative criteria / Systems	Commercial speed (km/h)	Service reliability	Space occupation	Air pollution	Noise in street	Energy consumption	City network coverage	Image	Construction costs
Bus	10-20	☹	☺☺	☹	☺	☹	☺☺☺	☹☹	☺☺☺
BRT	15-25	☺	☹	☹☹	☹	☺	☺☺	☺	☺
LRT	18-35	☺☺	☺	☺☺☺	☺☺	☺☺	☺	☺☺☺	☹
Metro	30-45	☺☺☺	☺☺☺	☺☺☺	☺☺☺	☺☺☺	☹	☺☺	☹☹

Figure 8-Examining the quality indicators of public transportation

4. Challenges and Opportunities

Despite the promising outlook, several challenges hinder the widespread adoption of electric public transportation in Iran. The high initial costs of electric buses and the necessary infrastructure pose significant barriers. Moreover, public awareness and the perceived reliability of public transport systems are critical factors influencing ridership. A study in Kerman identified that while residents are aware of the benefits of public transport, issues such as inadequate facilities and information about schedules deter usage (Bahreini, 2016).

4.1. Benefits of Electric Public Transportation

Electric public transportation has significant benefits in various aspects, the most important of which are:

1. Reducing pollutant emissions: Replacing diesel vehicles with electric buses can reduce emissions of carbon dioxide, nitrogen

oxides, and particulate matter and improve urban air quality.

2.Reducing dependence on fossil fuels: Using renewable energies in the transportation sector reduces fossil fuel consumption and increases energy security.

3.Increasing economic efficiency: Economic studies show that despite high initial costs, electric buses have lower operating costs in the long run and allow for reduced maintenance costs.

4.Promoting public health: Reducing air pollutants reduces respiratory, cardiovascular, and cerebrovascular diseases and increases the quality of life of citizens.

4.2. Challenges of electric public transport systems:

1. Economic challenge:

Establishing and operating electric public transport systems such as metros or trams requires significant initial investment. These costs may be challenging for some cities or countries.

Solutions to address economic challenges: Financial incentives and government subsidies for the purchase of electric vehicles. Investing in local battery technologies and charging equipment to reduce import costs. Developing public-private partnership (PPP) models to increase investment in this area.

2.Technical challenge

To launch electric public transport systems, the existence of appropriate infrastructure such as a strong power grid, charging stations and dedicated routes is essential. Developing this infrastructure may be time-consuming and costly.

In the case of electric vehicles such as buses, limitations in range and battery charging time can be a challenge for continuous and efficient operation.

Solutions to address technical challenges: Developing smart charging networks and wireless charging infrastructure at transit stations. Improving next-generation battery technologies such as lithium-sulphur and supercapacitors to increase vehicle range. Designing a hybrid fleet including electric buses and complementary energy systems such as dynamic charging.

3.Social Challenge

In some cases, there may be resistance from citizens or relevant institutions to the transition from traditional to electric systems. This resistance can be due to old habits or economic concerns. However, long-term savings in fuel costs and reduced maintenance can compensate for these initial investments. Iran’s commitment to this transition requires strategic financial planning and potential international partnerships.

Social Challenge Solutions: Implement education and awareness programs to increase public acceptance. Plan for job changes and train new skills for transportation industry workers. Develop integrated transportation systems that make the use of electric vehicles attractive, efficient, and affordable for users.

To overcome these challenges, it is essential for policymakers to focus on improving the infrastructure and providing better information to the public. Enhancements in waiting facilities and the overall attractiveness of public transport can significantly increase ridership and support the transition to electric systems.

What are the factors influencing the choice of transportation system from the perspective of policymakers and passengers?

1. Economic costs: Policymakers are concerned with optimizing the costs of building and operating transportation systems. Travelers are also concerned with travel costs and affordable options.

2. Service quality

Travel safety: One of the most important factors for travelers is the safety and security of travel. Policymakers must ensure that transportation systems have appropriate safety standards.

Convenience and travel time: Waiting time and travel comfort are key factors in choosing a transportation system. Travelers look for the route that takes the least time and is convenient in terms of comfort.

3. Accessibility

Accessibility: Easy access to stations and connection points is very important in choosing a transportation system. This helps policymakers to develop systems that are easily accessible to everyone.

4. Environmental Impacts

Environmental issues: Increasing focus on the environment and reducing emissions has led travelers to prefer cleaner options. Policymakers should pay attention to the environmental impacts of transportation systems to contribute to sustainable development.

5. Social and Cultural Support

Cultural and Social Factors: People may be more inclined to use some systems than others, depending on the history and culture of their society. For example, public trust in service providers plays a significant role in choosing a transportation system.

6. Macro-Policy Making and Planning

Role of Policymakers: Policymakers play a vital role by determining strategies and laws related to the development of transportation systems. Choosing the right systems requires macro-planning and careful analysis to make the optimal choice.

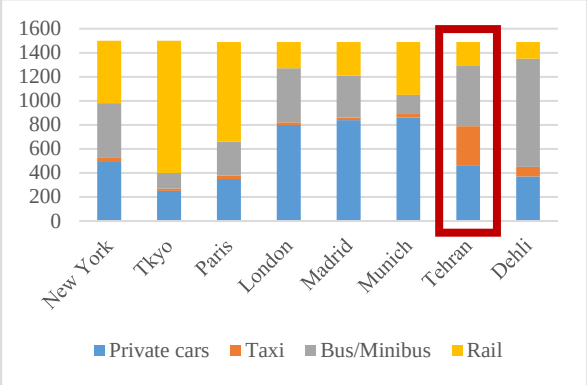

Figure 9- Factors influencing the choice of transportation system from the perspective of policymakers and passengers

5. Summary of the comparison of electric and non-electric transportation systems:

Table 2-Comparing the electric and non-electric public transportation systems

Systems	Strengths	Weaknesses
Non-Electrical	-Low initial capital -Existence of local experience and knowledge -High adaptability to urban roads	-Low operating speed -Limited capacity -High pollution -Higher fleet depreciation -Higher operating costs -Larger lane occupancy
Electrical	-Higher speed -Higher capacity -Use of clean energy -Visual appeal -Diversity in power supply system -Easy access for people with disabilities	-High initial capital -Lack of construction and operation experience

6. Conclusion

The increasing development of human society and its need for the simultaneous development of various transportation methods have created various effects and fragility of the human environment. Different types of transportation each have a significant impact on the environment around them. Of course, sometimes these effects are positive and most of the time negative, but what is important and should be paid attention to is observing the principles of environmental assessment of construction projects before the implementation of the project and in the initial studies and phase one of that project. In this article, the environmental effects of urban railways compared to other transportation systems on air quality, traffic reduction and accident rates were examined in

detail. The results of this research show that urban railways have positive effects on air quality and environmental pollution reduction due to lower energy consumption and lower production of pollutants. The use of urban rail reduces traffic congestion and improves urban traffic flow, which plays an important role in reducing accidents and increasing road safety.

The environmental benefits of urban rail include reduced air and noise pollution, reduced fossil fuel consumption, and reduced greenhouse gas emissions. This transportation system also reduces the use of urban land for streets and parking lots, which improves urban space and increases green spaces. On the other hand, other public and private transportation systems have more negative effects on air quality and urban traffic. Excessive use of cars, increased traffic and road accidents, and increased air and noise pollution are among the problems of these systems.

This article examines and compares the positive and negative impacts of urban rail and other transportation systems from various environmental aspects. The results show that the development and expansion of urban rail, as one of the most effective sustainable transportation solutions, can lead to improved air quality, reduced traffic, and reduced accident rates in cities. Therefore, attention and investment in this field are essential to preserve the environment and improve the living standards of citizens. The task of preserving the urban environment in urban development and management programs has been subject to numerous inconsistencies and neglect. Therefore, making decisions regarding organizing and improving the current situation with the help of newer laws is a matter that should be diligent in strengthening the real position of urban management, urban development, development plans, and explaining the duties of each of the elements involved in protecting the environment. Also, considering the differences between the cities of the country in terms of environment, culture, history, politics, economy, and society, it is not possible to apply a specific mode of transportation to all cities of the country without considering these factors. Rather, it is necessary to use various transportation methods and patterns for each city, considering each of the mentioned factors, and in a sense, Iranian engineering should be used. As mentioned, urban transportation is a vast and complex matter, and numerous forces and factors are involved in its growth and development, and in order to reduce the environmental impacts of transportation, one should avoid choosing a single method that is far from reality.

Suggested solutions for managing the conflict between electricity supply and air pollution:

• Use of renewable energy: Increasing the use of renewable energy such as solar and wind energy can help reduce the need for gasoline and also reduce air pollution.

• Development of public and green vehicles: Increasing public transportation facilities and encouraging the use of green vehicles can help reduce the use of gasoline and reduce air pollution.

• Research and development of new technologies: Research and development of new technologies such as electric vehicles and new technologies are essential to reduce the use of gasoline and reduce air pollution.

• Public education and culture: Awareness programs, providing information about the benefits of electric public transportation through media and social networks.

• Training of drivers and transportation employees: Holding training courses for the correct use of electric fleets and technical repairs.

• Encouraging people to use electric public transportation: Providing special discounts for passengers to increase the use of this system.

• Environmental protection policies: Political decisions to protect the environment and encourage the use of renewable energy and reduce gasoline use should be prioritized.

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