[World Automotive Powertrain Outlook 2023]

RESULTS SUMMARY - WORLD

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File

SCOPE

8 areas & 29 countries in detail, including the major players



Area	Country
NAFTA	Canada, Mexico, USA
South America	Argentina, Brazil, Chile, Colombia, Peru
Europe	France, Germany, Italy, Spain, UK and the rest of EU-27+EFTA
Middle East	Iran, Saudi Arabia, United Arab Emirates
China	China
Russia	Russia
Asia OECD	Australia, Japan, New Zealand, South Korea
Rest of Asia	India, Indonesia, Malaysia, Pakistan, Philippines, Thailand

Regional market leaders

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Contextualization

- H2 Powertrain update & worldwide H2 costs
- Authorization matrix
- Energy costs

Focus on Regulation Groundwork



Results for the Main Countries



Global Outlook





(RE)DEFINITION OF FUEL CELL POWERTRAIN ARCHITECTURE & COSTS

Sizing - Worldwide references

Powertrain	Segment	Battery Size (kWh)	FC Power (kW)	Weight H2 (kg)
FCEV	K1	2,3	100,0	7,0
PHFCEV Low	K1	11,5	45,0	5,1
PHFCEV High	K2	33,0	30,0	6,5
FCEV	D Low	1,5	110,0	5,6
PHFCEV Low	D Low	18,0	45,0	4,0
PHFCEV High	D Low	43,0	26,5	5,0

For the other relevant segments, values are resized via the relative power ratio

Price



For all segments in all areas, the corresponding motor price is inherited from the corresponding BEV Very High case (as the power to be considered depends on the area)

FCEV = Fuel Cell Electric Vehicle PHFCEV = Plug-in Hybrid Fuel Cell Electric Vehicle





ENERGY - GREEN H2 PRICE AT THE PUMP FOR THE MAIN MARKETS





ENERGY PRICES AT STARTING POINT - FUELS & ELECTRICITY



Multiple citations, more details are given in the annexes





ENERGY PRICES AT STARTING POINT - GAS





- LPG is the cheapest in Saudi Arabia, at only 0,24€/L, followed by Japan, China, and the USA at almost the same price level
- In India and Brazil, the LPG price is relatively higher

CNG Price at Starting Point (€/kg)



- CNG is also the cheapest price in Saudi Arabia, followed by China and India with a price lower than 1€/kg
- The CNG price in the USA, Brazil, and Japan is a bit higher, ranging between 1,13€/kg and 1,22€/kg

NB: Medium- and long-term price projections consider some level of biogas incorporation

Multiple citations, more details are given in the annexes





REVIEW OF FUEL CONSUMPTION: MORE CONTAINED REDUCTIONS



No real tendency to more fuel consumption reduction

- No tendency to an important fuel consumption reduction in ICE powertrains.
- At a given segment, vehicle mass and size increase.
- The rise of the SUV is limiting the fuel reduction potential for the High segments.

Fuel consumption updates

- Currently, the fuel consumption dynamic by LV segment **depends on the geographical area** (heterogenous deployment of fuel consumption reduction efforts, with a greater potential for reduction in the emerging markets)
- The starting point of some fuel consumptions have been reviewed compared to WAPO 2022. For example, for the gasoline PWT:

L/100km	Area	WAPO 2022	WAPO 2023	Gap %
Dhigh	Europe	7,79	9,00	+16%
	China	8,74	10,10	+16%



Consumption reduction updates

- Estimations of fuel consumption reduction by vehicle segment is geographically independent.
- Fuel consumption reductions have been reduced in comparison with WAPO 2022. Examples of fuel consumption reduction until 2040:

China	Gaso- line	Die- sel	CNG/ LPG	Elec.	H2
А	-5%	-3%	-3%	-3%	-10%
D high	-10%	-5%	-5%	-5%	-15%
K2	-8%	-4%	-4%	-5%	-15%

* Trends in the global vehicle fleet 2023 from 1-1 interviews, GFEI, EPA, IEA and ICCT





A BATTERY PACK PRICE SIGNIFICANTLY CHEAPER IN ASIA

* Only Europe data was updated in WAPO 2023



- The price of batteries is experiencing a long-term downward trend, primarily due to economies of scale resulting from increased battery production.
- The green growth scenario estimates a **decrease of 12% in 2030 and 17% in 2040** in comparison to the green constraint scenario.

1 EUR = 7,7 RMB

Battery pack evolution price (€/kWh) **Green Growth** 200 150 100 70 50 56 37 2020 2025 2030 2035 2040

• The battery pack price of China, Russia & Rest of Asia is lower than Europe thanks to a complete supply chain for batteries, from the production of raw materials to the manufacturing of cells and modules. Asian manufacturers benefit from economies of scale and reduce transportation costs. They also have a lower labor cost than Europe.



Exchange rates:

9



STABILIZED REFERENCE POWER FOR EACH VEHICLE SEGMENT

Reference power - 2023 hypotheses update / discussed with WAPO members

Punctual reference power updates

- For a given segment, **vehicle masses increase** * (rise of the SUV).
- There is no more tendency for a downsizing of vehicle segments. Vehicle power increases over time and electric vehicles are no exception.
- Some reference power have been reviewed compared to WAPO 2022. For example:

	Area	WAPO 2022	WAPO 2023	Gap %
	NAFTA**	190	250	+32%
D high	South America	147	155	+5%
	China	151	161	+7%

Reference power tendency towards balance

- Evolution over time of reference powers have been updated compared to WAPO 2022.
- There is a **tendency towards balance for reference power** of all vehicle segments over time.

* Trends in the global vehicle fleet 2023, GFEI

** EPA Automotive Trends Report



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WAPO 2023

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METHODOLOGY OF POLICY CONSTRAINTS



CO2 regulation framework

- Fuel Economy Policy applied to OEM in most automotive markets
 - > Main driver for fuel efficient technologies

As a demand-driven model (TCO), the WAPO does not deliver a compliance perspective

- Zero and Low Emissions sales targets such as Mandates and ICE bans
- > Limit the technology offer to ZEV or LEV only WAPO does consider all announced L/ZEV targets and applies them accordingly

Air Pollution Policy

Air Quality standards in most advanced countries are very stringent...

BUT

Developing countries do not have strong air pollutant policies!

The WAPO technology offer depends on the stringency of air pollutant policy:

- Today and for the emerging countries following more mature markets example, technologies that have high pollution levels are banned accordingly
- The application of new air pollution policy is gradual, considering the maturity of the market Therefore, the ban of the most polluting technology only occurs late for emerging markets

Taxes and Subsidies

%

There are fiscal incentives or charges applied to vehicle purchase and usage depending on a wide range of criteria: fuel type, vehicle body, vehicle length, vehicle weight, engine size, vehicle price, fuel consumption, CO2 emissions and customer (private or professional use)

WAPO assumes an average vehicle characteristic for each segment, country and powertrain that defines the tax level:

- Typically, high-end and luxury vehicles do not represent an average vehicle
- When some policies vary locally at a state level, we took a representative sample state





EVERY REGION IN THE WORLD IS PUSHING FOR ZEV SALES

Global ZEV Mandates and ICE Ban planning

Every main region has a country pushing Low Emission Vehicles sales

- Asia OECD: Japan, Australia and NZ
- South America: Chile
- North America: Canada and California
- China

 (\mathcal{O})

the European Union

There are **not yet well-established targets** in India, South-East Asia, Russia or the Middle-East.

Enforcing ZEV Mandates and ICE Ban limit the PWT choice to **two technologies: BEV** and H2 Fuel Cell powertrains.







UPDATE ON WORLDWIDE POLICY (1/2)

Country	Nature of Change	Impact	Dynamics	Source
Mexico	Tax on Acquisition: Based on Vehicle Price and Exemption for ZEV	Progressive tax on Vehicle Price that is exempted for electric and hydrogen vehicles. Gap in tax is greater for upper segments.	No dynamics, Same tax scheme used for the 2023-2040 period	Decreto de Ley Federal (LFISAN) actualizado en 2022
USA	Incentive on Zev Purchase by two Mechanisms: Bonus and Credit Tax	New budget from IRA to ZEV incentives up to 7500 CUSD and extended aid to vehicle purchase	Extension to 2027	Analyzing the Impact of IRA on EV Uptake in the US, ICCT, 2023
Brazil	Tax on Acquisition with three mechanism: ICMS, PIS, IPI and Import Tax. Change in IPI and Import Tax	IPI is defined from vehicle category, vehicle segment, fuel type and energy efficiency. Energy efficient, electric and light vehicles have the lowest tax percentage (5,2%). Diesel, heavy and not energy efficient vehicles have the highest tax percentage (18,9%)	Import Tax was low for Electrified Vehicles, but new tax reform is making import tax equal to 35% for all fuel types by 2025. In Green Growth we expect to have either a tax change or a local industry that makes this import tax zero again by 2029.	Decreto TIPI 2022 and <u>Desde enero</u> vehículos electrificados vuelven a pagar impuesto a la importación en <u>Brasil - Mobility Portal: Noticias</u> sobre vehículos eléctricos
Peru	ISC is Tax on Acquisition, government is studying a revision on IGV	No change on ISC: Depending on vehicle price and fuel type with a penalty for Diesel Powertrains and Upper segments	No dynamics, Same tax scheme is applied for the 2023-2040 period	Impuesto Selectivo al Consumo - Partidas Arancelarias
Colombia	Discount on VAT, Excise Tax for ZEV, Usage Tax percentage	ZEV are exempted from VAT and have a reduced Excise Tax (5%) and have a reduced usage tax percentage (1%)	No dynamics, Same tax scheme is applied for the 2023-2040 period	Minambiente Colombia and Impuesto sobre vehículos automotores Bogotá





UPDATE ON WORLDWIDE POLICY (2/2)

Country	Nature of Change	Impact	Dynamics	Source
India	Acquisition taxes are mainly divided in two categories: GST and Compensation cess. Update to the mechanism and inclusion of road tax following Delhi tax scheme.	The acquisition tax is based on vehicle length, fuel type and engine displacement. The tax percentage favors Small, Electric or Hybrid Vehicles. The road tax in Delhi depends on vehicle price and fuel type.	No dynamics, Same tax scheme is applied for the 2023-2040 period	Passenger car taxation in India, ICCT 2023 and Overview of Asian and Asia-Pacific Passenger Vehicle Taxation Policies, ICCT 2022
Malaysia	High Taxation on vehicle acquisition. Change in ZEV exemption and dynamics.	Acquisition Tax is exempted for ZEV Vehicles.	Exemption lasts until 2028	Overview of Asian and Asia-Pacific Passenger Vehicle Taxation Policies, ICCT 2022
Indonesia	New scheme based on fuel type, vehicle price, engine capacity and CO2 emissions	Lower tax percentage for EV, HEV and H2 vehicles depending on their CO2 emission level and engine capacity	No dynamics, Same tax scheme is applied for the 2023-2040 period	Overview of Asian and Asia-Pacific Passenger Vehicle Taxation Policies, ICCT 2022
South Korea	Acquisition Tax both fixed and on percentage favors ZEV	Bonus on EV vehicles and higher for H2 vehicles. Reduction on tax percentage for hybrids and ZEVs	Bonus lasts until 2028	Hyundai website and Press release from Korean Environment Ministry
New Zealand	Clean Car Discount in New Zealand applies on Acquisition tax according to CO2 emission levels	Less or equal than 100 g CO2/km have a rebate and higher than 150 g CO2/km have a fee	The upper limit of the feebate scheme is reduced similar to bonus malus logic	s New Zealand Transport Agency





FOCUS USA - ASSUMPTIONS ON AUTOMOTIVE POLICY

Federal and State policies regulate the market with a mixture of mechanisms

- Fuel Economy Policy is applied as a CAFE Standard with an upcoming target of 49 mpg for passenger cars and light trucks for sale year 2026 (vs. an average fuel economy of 25 mpg in 2021). The fuel economy improvement in the new rule of CAFE is more stringent.
- A ZEV Mandate applied in California and another 14 affiliated states is required to achieve an increasing zero emission sales share. The long-term objective is a 100% zero emission target by 2035. PHEV powertrains will be phased out of the ZEV Mandate by 2026.
 - An increase in stringency of the ZEV target was projected from 2025 to 2035, as well as a decrease in credits per vehicle for all scenarios; an increase in US states applying a ZEV Mandate was implemented in Green Growth only.
- At a federal level, long term objectives aim at 50% of zero-emission vehicles by 2035 and carbon neutral vehicle sales by 2050. Some states are considering more ambitious objectives: in California, 100% of new vehicles sales will by zero emission by 2035. New York, New Jersey and Massachusetts are considering the same target.
- The Tax scheme in the United States is state-dependent, so the outcome average tax level was divided into four mechanisms, common to all Scenarios:
 - An average purchase tax
 - A Tax credit for zero emission vehicles (up to 7500 USD for electric and fuel cell vehicles)
 - A low emission vehicle incentive (up to 4500 USD for plug-in and fuel cell vehicles)
 - A Gas guzzler tax for high emitting vehicles (up to 7700 USD applied for vehicles with a fuel consumption above 10 l/100km)

All tax incentives will be phased out by 2025





FOCUS CHINA - ASSUMPTIONS ON AUTOMOTIVE POLICY

With national subsidies soon phased out, Dual Credit Policy will be the main national regulatory approach

- ▶ In April 2020, Beijing announced that subsidies will be reduced from 2020 to 2022 by 10%, 20%, and 30%, respectively. The national subsidy program is supposed to be phased out this year but is extended to **end of 2023**.
 - **Tax exemptions** for New Energy Vehicles NEV * will also be extended to 2023.
- As the country will soon phase out its national purchase subsidy program, the main national regulatory approach is the "Dual Credit Policy".
 - Manufacturers are required by **corporate average fuel consumption (CAFC)** credit requirements to make fuel-efficient vehicles. The fleet average fuel consumption target in 2020 is **5L/100km** et will be lowered to **4L/100km** in 2025.
 - Yearly tightening fuel economy standards will motivate manufactures to produce more NEVs and thus collect NEV credits. The government's NEV credits goals for 2022 and 2023 are **16**% and **18**% respectively. We assume that the percentage will increase linearly till 2030 and reach **32%**.
- New Energy Vehicle Industrial Development Plan (2021-2035):
 - By **2025**, **20%** share for NEVs in annual new vehicle sales.
 - By 2035, more than 50% of sales will be NEVs; pure ICEs will not be permitted, and all conventional energy passenger cars will be minimum MHEVs; public vehicles will be 100% electrified and fuel cell vehicles will be commercialized.
 - By **2040** for **Green Growth** only, the electrification of the powertrain mix is stronger due to a goal of **100% electrified and fuel cell vehicles**; MHEVs will no longer be allowed.

* NEV stands for New Energy Vehicle, it includes BEV, PHEV and FCEV



Source: ICCT, Ministry of Industry and Information Technology of China

2022 - 2023 national subsidies phasing out

NEV	NEV Range (km)		2023
DEV	300 - 400	1300 €	1300 €
DEV	>400	1800 €	1800 €
PHEV	All	680 €	680 €

Source: Ministry of Industry and Information Technology of China

Exchange rate:

1 EUR = 0,13 RMB



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IMPACT OF THE REWORKED FUEL CELL PWT ARCHITECTURES ON TCO



FCEV is the most expensive architecture of H2 Powertrains. PHFCEV High benefits from a high decrease on battery pack costs and is cheaper to use than the other three. There is a high uncertainty on H2 fuel price and components that could give or take an advantage on H2 powertrains.



GUIDEBOOK FOR WAPO RESULTS



BEV technology choice

- BEV autonomy defines the compatibility of a technology with a customer niche, via daily and exceptional kilometrage ranges.
- BEV Low covers only the customers needing low kilometrage needs.
- BEV High covers more customers and BEV Very High even more.
- As a result, most usages covered but BEV can not cover all usages.
- When an ICE ban is applied, there is an exemption: the BEV available for a segment with the highest autonomy is assumed to cover all usages **if and only if** there is no H2 FC technology developed for that segment.



Fuel price update

- In 2023, fuel prices are not stable yet there is a high volatility and geopolitical context that can impact fossil fuel prices anytime.
- Fuel prices are lower in 2023 compared to 2022 including gasoline, diesel, electricity and CNG.



Phasing out of ZEV incentives

- Government incentives on ZEV are costly if sales of ZEV soar.
- Thus, to stabilize government expenditure we have phased out the incentives in the 2025-2030 period for all countries.
- When a ZEV incentive is removed, TCO of ZEV increases and the ZEV mix is impacted.
- We apply a smooth transition for the phasing out of incentives. In practice, the removal of incentives can be more radical.





EUROPE - AN EV TRANSITION ENTERING THE EARLY MAJORITY



BEV in Europe experience a high increase due to 2 main levers:

- Policy schemes for Air pollution from 2026 limiting some ICE technologies and a full ICE ban in 2035.
- A significant decrease on electric vehicle component costs.

Inside Europe we have different dynamics on EV sales in the 2020s . Some countries are far ahead of the transition: Norway, Sweden, Iceland, Finland and Denmark. Some other countries are lagging: Bulgaria, Poland, Slovakia, Croatia, etc. For these laggard countries, the ICE ban target will be challenging.







Green Growth



EUROPE - SMOOTHER TRANSITION TO THE ICE BAN IN 2035



Green Growth produces a more linear pathway to the ICE Ban in 2035 than Green Constraint this due to the assumptions on battery prices and higher fossil fuel prices.

H2 vehicles experience a more rapid deployment in Green Growth due to the specific assumptions:

- A more significant reduction of H2 price and a lower target by 2040.

- Lower components costs for H2 powertrains with a consistent decrease even post 2035 that make H2 powertrains competitive compared to BEV.











CHINA - MAINTAINING THE COURSE OF ELECTRIFICATION



Electric vehicles dominate sales in China, and hydrogen vehicles remain marginal even in the long run. This is primarily due to the relative high price of green hydrogen.

The plug-in hybrid vehicle sales would see a slight increase in the short term then remain stable until 2040.

The market share of CNG will see a minor rise in the near future, remaining steady in LCV until its 2030 phaseout, especially in regions like Xinjiang and Sichuan, due to low CNG prices.







Green Growth



CHINA - EN ROUTE TO NET ZERO IN 2060



A notable rise of sales in hydrogen vehicles will be seen from 2030. In this scenario, hydrogens prices are much more attractive, making the TCO for hydrogen vehicles more favorable than the Green Constraint Scenario. There should be more PHFCEV High than PHFCEV Low, for PHFCEV High benefits from having a larger battery. The low battery prices in China ultimately allows it to have a lower cost than PHFCEV low, which uses a smaller battery but a larger fuel cell stack.









USA - A SLOW ELECTRIFICATION PROCESS



Phasing out Plug-in hybrids of the ZEV Mandate reduces the adoption of this powertrain, but it remains a competitive alternative to long-range BEV in states that are not concerned by the ZEV Mandate.

After the major rework on the Fuel Cell architectures - including on the US power ratio vs Europe - these powertrains now show a promising deployment and an 8% market share in 2040.

ZEV could account for more than 45% of the US sales in 2040.



Vehicle sales powertrain mix forecast - USA: LCV (Green Constraint)





Green Growth



USA - MORE STATES WILL JOIN CALIFORNIA ZEV MANDATE



USA states will transition to ZEV at different speeds: California and other 14 states will lead the pack. The rest of the country will follow if the zero-emission transition within the first movers is successful: Green Growth assumes that more will then join the "ZEV" states, with ZEV reaching a combined market share of 63% in 2040.

However, in a scenario more favorable in terms of Fuel Cell component and H2 costs, the geographical extension of the ZEV mandates mostly benefit to the related powertrains on the long term: the FC/BEV distribution of the ZEV sales will then be 37%/63%.



Vehicle sales powertrain mix forecast - USA: LCV (Green Growth)





JAPAN - THE HYBRID STRATEGY



Unlike other mature markets with ambitious and binding policy schemes, Japan is lacking a policy push to boost ZEV sales. The phasing out of ZEV incentives can potentially slow EV evolution.

Japan will massively sell hybrid vehicles to respect the transition goal to full hybrid or zero emission vehicles by 2035

Since Japanese OEMs will be capable of producing large volumes of ZEV for foreign markets an industry push on ZEV seems possible by 2040









Green Growth



JAPAN - FULL ZEV TARGET IN 2050





Vehicle sales powertrain mix forecast - Japan: LCV (Green Growth)







SOUTH KOREA - KEEPING OPTIONS



South Korea has very favorable framework for H2 vehicles but there is only a very low volume of sales. The concern is that the H2 price remains high.

South Korea does not have any binding mechanism to limit ICE vehicles thus the 2040 mix combines different powertrain technologies.

Local OEMs are global with a very clear EV product line that can be promoted locally to drive EV sales up.



Vehicle sales powertrain mix forecast - South Korea: LCV (Green Constraint)





Green Growth



SOUTH KOREA - NO MORE MHEV IN 2040



Green Growth in South Korea is one key market to study all favorable conditions to H2 mobility: low fuel price, lower component costs for BEV and Fuel Cell powertrains and a government incentive. This context leads to a gradual increase of H2 sales after 2030.

Looking closely at the share of H2 powertrains by segment we see a market share of 25 to 40% in PC and 17 to 20% in LCV by 2040.

The policy goal in South Korea for Green Growth reflects a full hybrid and zero emission vehicle mix by 2040 Fuel Cell Plug-in vehicles in South Korea will progress in both PC and LCV





BDO



BRAZIL - THE FLEX FUEL SPECIFICITY



A change in vehicle policy that will no longer exempt EV from the import tax will delay EV sales outside of early adopters. No clear view of ZEV target for sales, the approach in Brazil covers WtW emissions.

Policies and local development of ethanol push the local industry to develop fuel economy technologies based on biofuels with hybridization.

The local automotive industry will need significant investments that can only take place if a policy framework favors EV TCO and its ecosystem must adapt to have higher volumes of EV in Brazil.

All Gasoline powertrains in Brazil are flex fuel, to be compatible with the local availability of ethanol.



Vehicle sales powertrain mix forecast - Brazil: LCV (Green Constraint)







INDIA - A VERY FAVORABLE POLICY TO DRIVE THE TRANSITION TO EV



India has a policy scheme that favors EV, local sales are at an early stage, but the fiscal conditions are favorable. India has a larger share of BEV Low that can be affordable and cheap to use. Nonetheless, it is uncertain if India will develop BEV High and Very High at the same rate than more matured markets.

How will India manage to produce EV designed for the local market and how much will they cost? This question is key to estimate the long-term volume and share of EV.

Electrified ICE vehicles will have a key role in reducing transport emissions in India as well.



Vehicle sales powertrain mix forecast - India: LCV (Green Constraint)





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Meta scenario



WORLD - THE GLOBAL DECARBONIZATION OF VL IS NOT HOMOGENOUS



Reminder of the scenario combination for the Meta outlook:

- Green Growth used for China, Europe, NAFTA, Japan and South Korea
- Green Constraint used for South America and Rest of Asia
- Liberal World used for Middle East / Stagnation used for Russia

There are large disparities between the 3 main leading automotive areas - China, Europe & NAFTA - and most of the rest of the world that is following a slower pace or has not begun with the ZEV transition.

From 2030 onwards, some markets lagging the ZEV transition might follow the example of mature markets specially if global initiatives (ZEV Alliance, ZEV Transition Council, Accelerating to Zero Coalition) change local conditions to favor ZEV.



Vehicle sales powertrain mix forecast - All areas: LCV (Meta scenario)







■ BEV ■ H2

80%

60%

SUMMARY ON ZEV DEPLOYMENT





100%



SUMMARY ON ZEV DEPLOYMENT





Green Growth anticipates higher ZEV vehicle volumes and market share. China leads with the largest BEV and H2 numbers. The market may not be exclusively comprised of ZEVs In 2040.

After the ICE ban, Europe is shifting towards the development of more hydrogen-powered vehicles than electric vehicles.

North America leads with nearly 25% of H2 powertrains by 2040. Green Growth's ambitious projections aim for significant global sales and market share increases by 2040.

However, some regions like South America, the Middle East, lag in ZEV powertrain adoption.





BATTERY DEMAND MAY REACH 4,8 TO 5,5 TWH WORLDWIDE



- Battery demand is mainly driven by China with a market share of 50% by 2030 and 36% by 2040.
- From 0,6 TWh of battery demand today to 5 TWh by 2040, the demand will increase ten-fold.



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CNG Price

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H2 Price

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