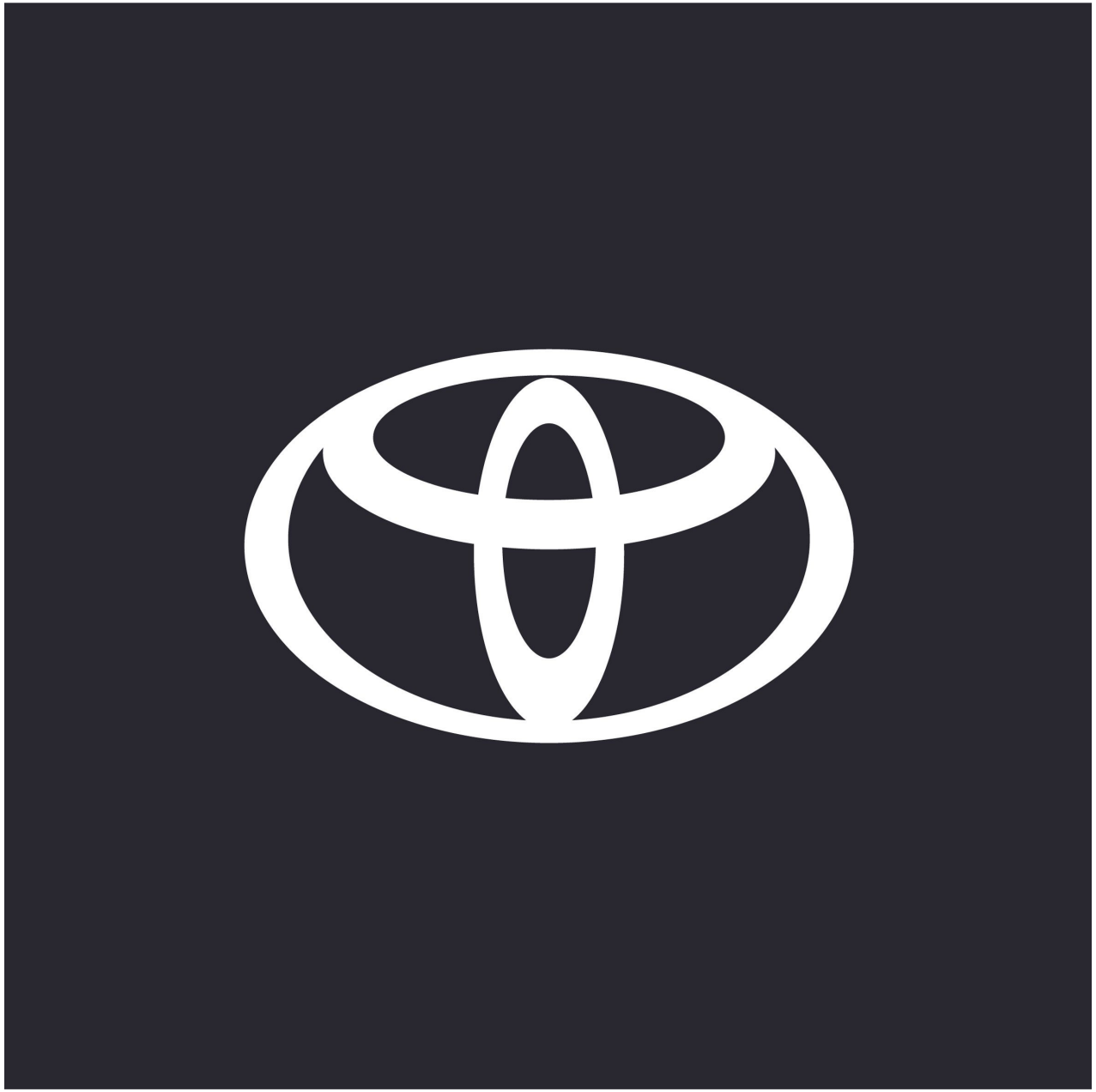

Toyota

A guide to

Sustainable Energy Alternatives

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Overview

- Lithium Ion and Alternatives
- Market Potential
- Alternative Technology breakdown
- Advantages and Limitations
- Actions and Recommendations

Lithium-Ion Batteries: What are they?

The Lithium-ion battery is one of the most consistent battery technologies when it comes to **reliability** and **efficienc**y.

Typically, the structure of these batteries consists of a **Cathode**, **Anode**, a **separator**, and an **electrolyte**. Lithium is a great cathode because of its natural tendency to lose electrons, high electrical potential, and small atomic structure for capacity.

Some other competitive advantages as a viable battery source consist of:

Power-to-Weight
Energy Density
Rechargeability
Lifespan
Scalability
Storage

Toyotas electrification efforts strives to reduce per unit costs, optimize battery efficiency, increase energy density, and reduce size as Lithium-ion batteries reach a peak

Lithium-ion: Do or Don't?

Drawbacks to this technology mainly reside in both it's **recyclability** and **material sourcing**.

- Batteries when recycled require extensive processing in breaking apart constituent materials diminishing cost-effectiveness. This is typically done through Smelting, Direct Recovery, and other intermediate processes
- Sourcing these batteries contribute heavily to water pollution and GHG pollution. Evaporation ponds sourcing lithium contribute to water scarcity and pollution. Hard rock mining contributes CO2 emissions in a ratio 15:1 per metric ton extracted.
- Ethical issues sourcing performance-enhancing minerals such as cobalt and nickel through "artisanal" mining manifest a dilemma in the advancement of batteries. This is the same for Lithium evaporation ponds and hard rock mining

Alternatives

Feasible solutions that correlate with Toyota's promise of achieving a more sustainable relationship with earth require:

- **Renewability**
- **Sustainability**
- **Ethical considerations.**

Standout candidates manifest as **Hydrogen Fuel Cell vehicles** and **Alternative battery electric vehicles**

Toyota has experience with developing a hydrogen combustion engine but is beside the point of decarbonization. Hydrogen fuel cells support electrification and utilize highly available and renewable resources.

Alternative Battery Technologies capitalize upon more sustainable & widely available materials such as Sodium or Sulphur as a cathode. This diminishes dependency, risk of scarcity, and Capital Expenses on lithium and other rare materials.

Hydrogen Market

Toyotas partnership with Shell Fuel reduces costs in the production and distribution of hydrogen improving market feasibility

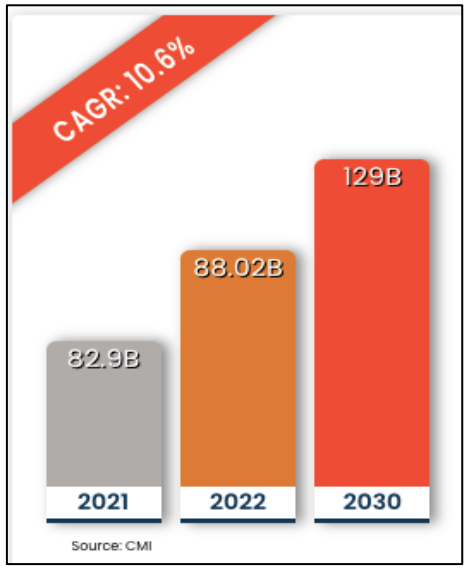
Economies of Scale achieve Cost reductions improving the price of hydrogen as more retail stations and hydrogen-based vehicles appear. Improving hydrogens value parity against competitive fuels catalyzes demand.

Toyotas Product mix with Light to Heavy transport supports multiple avenues of hydrogen integration into different transport systems

FCEV Growth

There is Dramatic Market Growth forecasted in the Hydrogen Automotive Industry. Since this tech is still in its infancy , large-scale potential is yet to be realized and infrastructure support is minimal

Electrification Market



BEV Growth

The Electrification market has significant infrastructure support and market maturity . It's more established viability and variable sources holds more security

Toyotas existing lineup of Battery Electric Vehicles, Hybrids, and Plug-ins are a testament to their commitment to support Carbon-neutrality.

Massive budget allocations of ¥8 million sustain electrification bringing EVs into a reasonable price range while reducing unit costs on battery production.

This competitive edge allows Toyota to provide a high value proposition on these products driving consumer demand.

Hydrogen Engine Technology

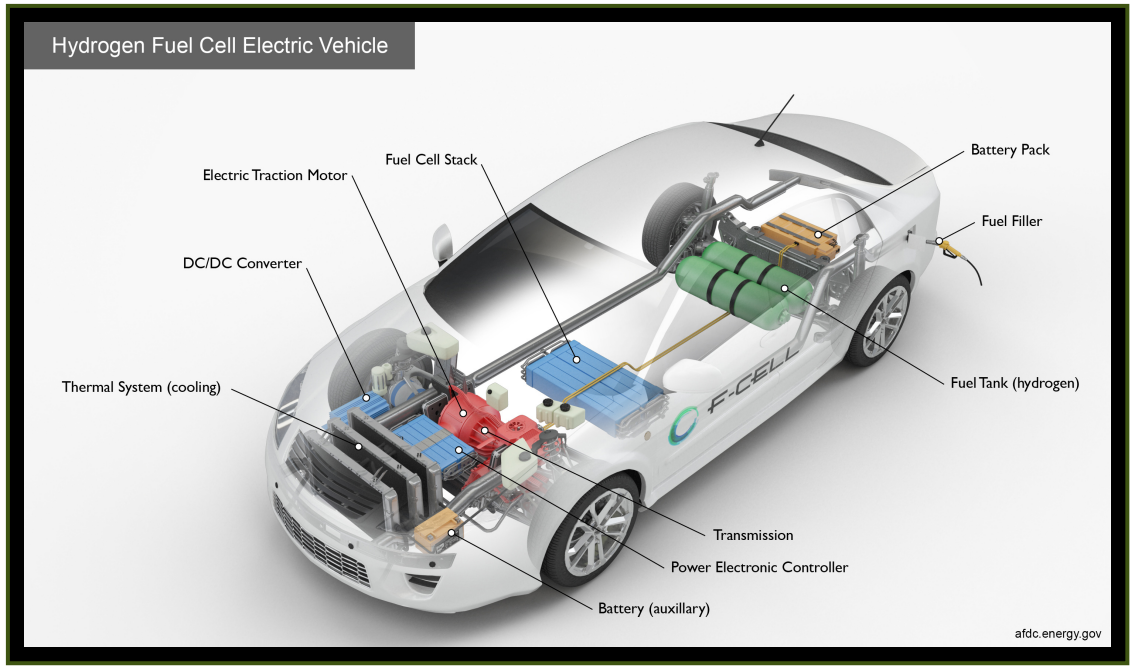
A Hydrogen engine contains two primary areas: The fuel tank for storage and the fuel cell system for energy. There is also a fuel filler for refilling capabilities

Fuel cells help power the traction motor to carry out motion and act much like a battery.

- Oxygen (Cathode)
- Hydrogen (Anode)
- Proton Exchange Membrane (Electrolyte)
- Layers of Separators
- Catalyst to split atoms

- **Emissions:**
  - (Direct) Water Vapor & Air
  - (Indirect) Upstream emissions

- **Sourcing Methods:**
  - Steam reforming (Natural Gas & Coal)
  - Electrolysis



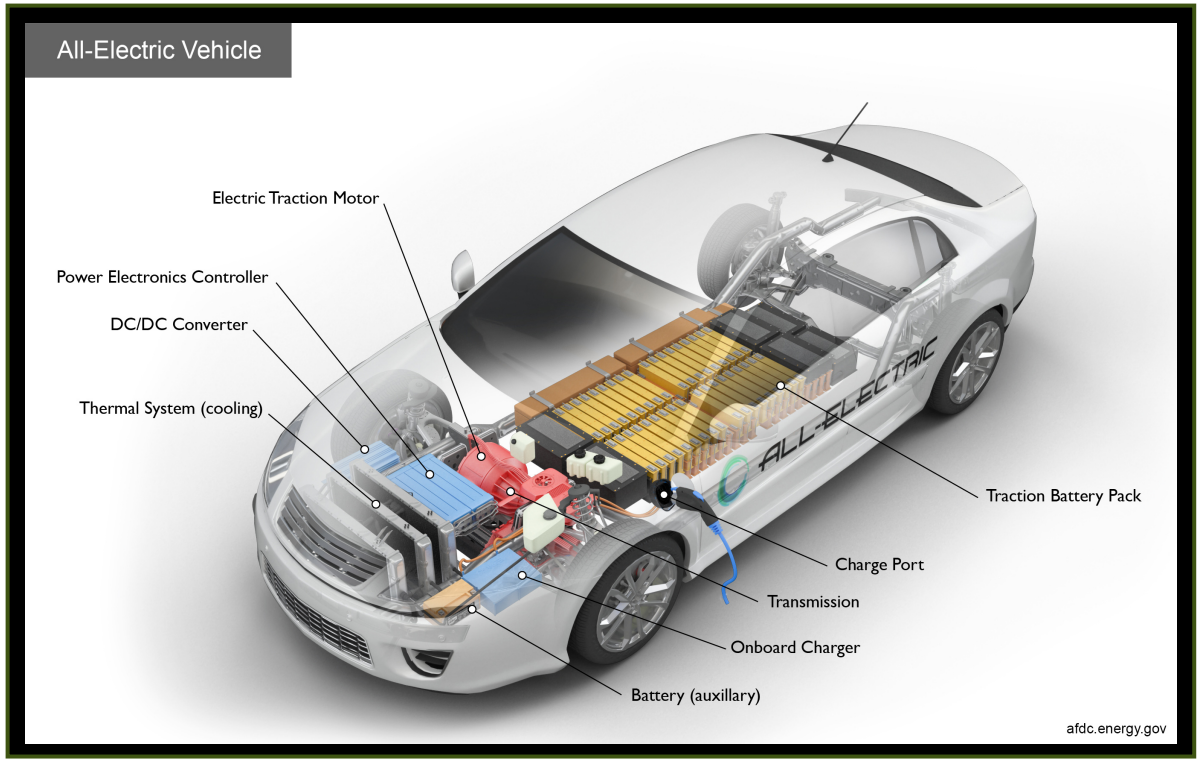
Battery Technology

A Battery Electric Vehicle contains a Traction Battery pack that stores electrical energy which is used by the traction motor to carry out mechanical motion.

This battery is recharged via an electrical charger typically powered by some local grid.

Battery Electric vehicles require less intermediation throughout a design (TBP to ETM) enabling an efficient integration

- **Emissions:**
  - (Direct) No Tailpipe emission
  - (Indirect) Upstream emissions
- **Sourcing Methods:**
  -Nuclear, Coal, Natural Gas, Renewable Sources



Advantages & Limitations

Hydrogen

Advantages:

- High energy density and efficiency compared to fossil fuel and lithium-ion
- Less material costs
- Climate friendly legislation and initiatives supporting adoption and improving market penetration

Limitations:

- Limited Fuel Tank Size
- Fuel Cell manufacturing costs
- Catalyst material of Platinum
- Market size, support, and infrastructure

Batteries

Advantages:

- Variability in different Cathode-Anode choices
- Advances in Solid-State electrolytes improving performance
- Specialized infrastructure and market maturity

Limitations:

- Prone to ageing
- Temperature performance
- Complex battery management systems
- Not as efficient compared to Lithium-Ion model

Recommendations

The following decisions improve company commitments to the sustainable commercialization and development of Alternative Automotive Energy.

- Financing Hydrogen Fuel Cell initiatives that assist with Manufacturing Costs, Operations, and R&D
- Engage in Business Ventures and Opportunities improving the market penetration of hydrogen
- Align Corporate Governance and Capital Expenditures to support Hydrogen Infrastructure
- Strategize potential Product Mix expansion with FCEVs
- Take advantage of Early Adoption securing competitive advantages and market

- Focus on Research and Development to maintain electrifications competitive edge and push beyond its peak
  - ❑ particularly Solid-State Electrolytes
- Conduct Feasibility analysis on the sourcing, production, and product viability of alternative Cathode-Anode battery tech
- Reinforce Ethical Guidelines and strengthen sustainability in supply chain of battery materials
- Reevaluate Weight of Capital Expenditures dedicated to Lithium-Ion production

Sustainable Course of Action

1. **Performing an Internal Analysis of the Business Process Toyota takes to develop Lithium-Ion batteries.**
2. **Understanding shortcomings, ethical questions, and improvements of this Business Process, and how alternative solutions may impact the optimization of this process.**
3. **Assessing the Cost and Revenue generated from such projects, along with the potential benefits it brings to specialize these technologies.**
4. **Setting goals and benchmarks to hold the company to a standard in the pursuit of Cleaner energy.**