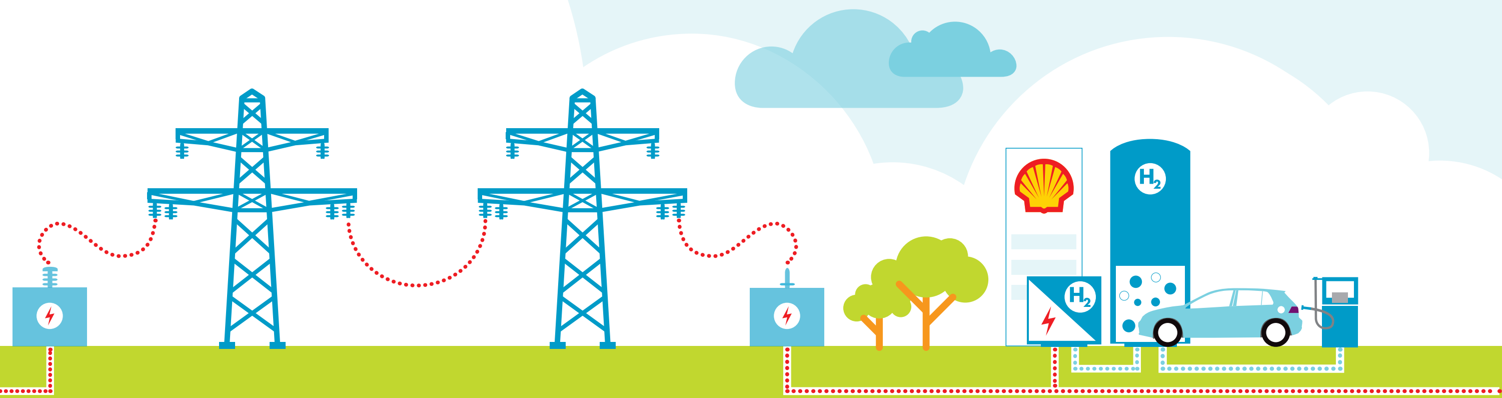
Shell

Hydrogen



TOWARDS COMPETITIVE REFUELING INFRASTRUCTURE

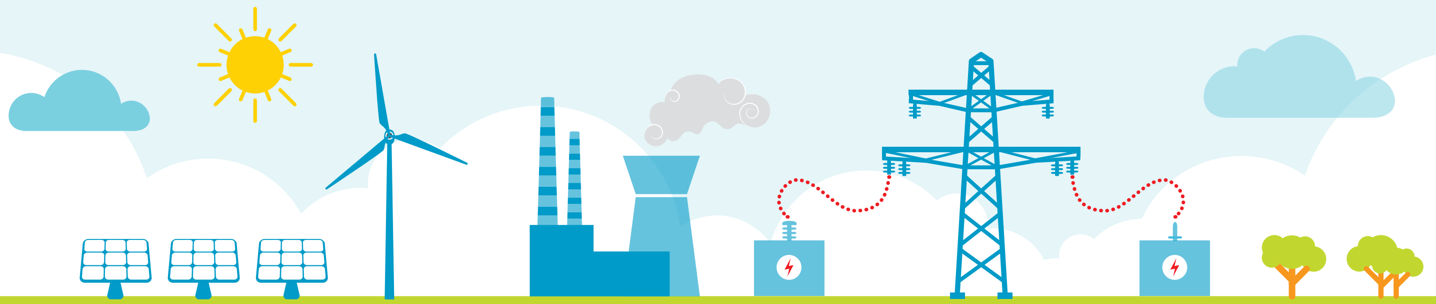
Fuel cell electric vehicles (FCEV), powered by hydrogen, provide long range and fast 3-minute refueling with zero emissions. They are an attractive option for many customers and will play a role alongside battery electric vehicles in a global low-carbon mobility future.

Hydrogen fuel cell technology is also highly suited to heavy duty applications where weight of the powertrain is an important factor. In addition to increasing the number of FCEV, delivering low-cost hydrogen refueling infrastructure is critical to realize this future.

After validating cost projections both technically and commercially with appropriate entities in the value chain, it is clear hydrogen can become cost competitive with liquid hydrocarbon fuels. On the way to price parity with incumbent mobility fuels, over 50% of the current cost can be reduced in the next 2 years with small actions taken. However, completing the journey to price parity requires participation and coordination across the hydrogen mobility value chain.

This is the market size required **(yellow arrow)** for these cost reductions **(blue bars)**

Hydrogen Light Duty Vehicle Retail Cost Roadmap (US Focus)



STANDARD HIGH-VOLUME MANUFACTURING

Process Optimization

In general, stations are designed to accommodate a wide range of H2 supply sources (on-site generation or delivered liquid/gas). By focusing on a single station design, and applying simple process optimization, station capital cost is reduced by 25%.

Manufacturing Overhead

Indirect manufacturing overhead costs currently account for up to 30% of current equipment cost. If a station provider produces 15-20 units/year of a single design, equipment cost reduction in excess of 30% can be achieved. This is in addition to benefits of process optimization.

Shell Hydrogen Refueling Station at Torrence, California

OPTIMIZED MAINTENANCE

Network Density

In addition to improving station reliability, more efficient use of maintenance infrastructure, and full utilization of service technician teams is required. Maintenance cost reduction in excess of 50% is expected for single operator station network densities of 40 stations in a region such as California.

Reliability Growth & Sustaining Engineering

By focusing on a few refueling archetypes, investing time and resources to improve reliability and lowering maintenance costs becomes feasible. Predictive health monitoring, component development, and continuous improvement of maintenance practices will reduce maintenance costs in excess of 60% when combined with the effects of a dense network. These effects are already being demonstrated in small single archetype fleet deployments.

LOW-COST RENEWABLE SUPPLY

Fixed Supply Contracts

Given expected FCEV production over the next 3 years, demand for retail hydrogen will provide the ability to sign firm supply contracts. This is expected to reduce supply costs by at least 25%. This cost reduction is available for fixed supply contracts as little as 3,000 kg/d or 4250 FCEV served.

Higher Demand

Scale is required to reduce plant costs and access low energy rates available from large solar and wind projects. In addition, a minimum volume of supply is required to justify investment into new liquefaction capacity to participate in the benefits of low-cost liquid distribution; hydrogen may be stored as liquid on retail sites, or re-gassed and compressed. Delivery of renewable hydrogen to the retail site for around 5 $/kg can be achieved for contracts as low as 10,000 kg/d (14,000 FCEV served) or less than 3 $/kg for 50,000 kg/d (70,000 FCEV served); a supply cost reduction of 70%.

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