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Hydrogen Production Technologies – An Overview

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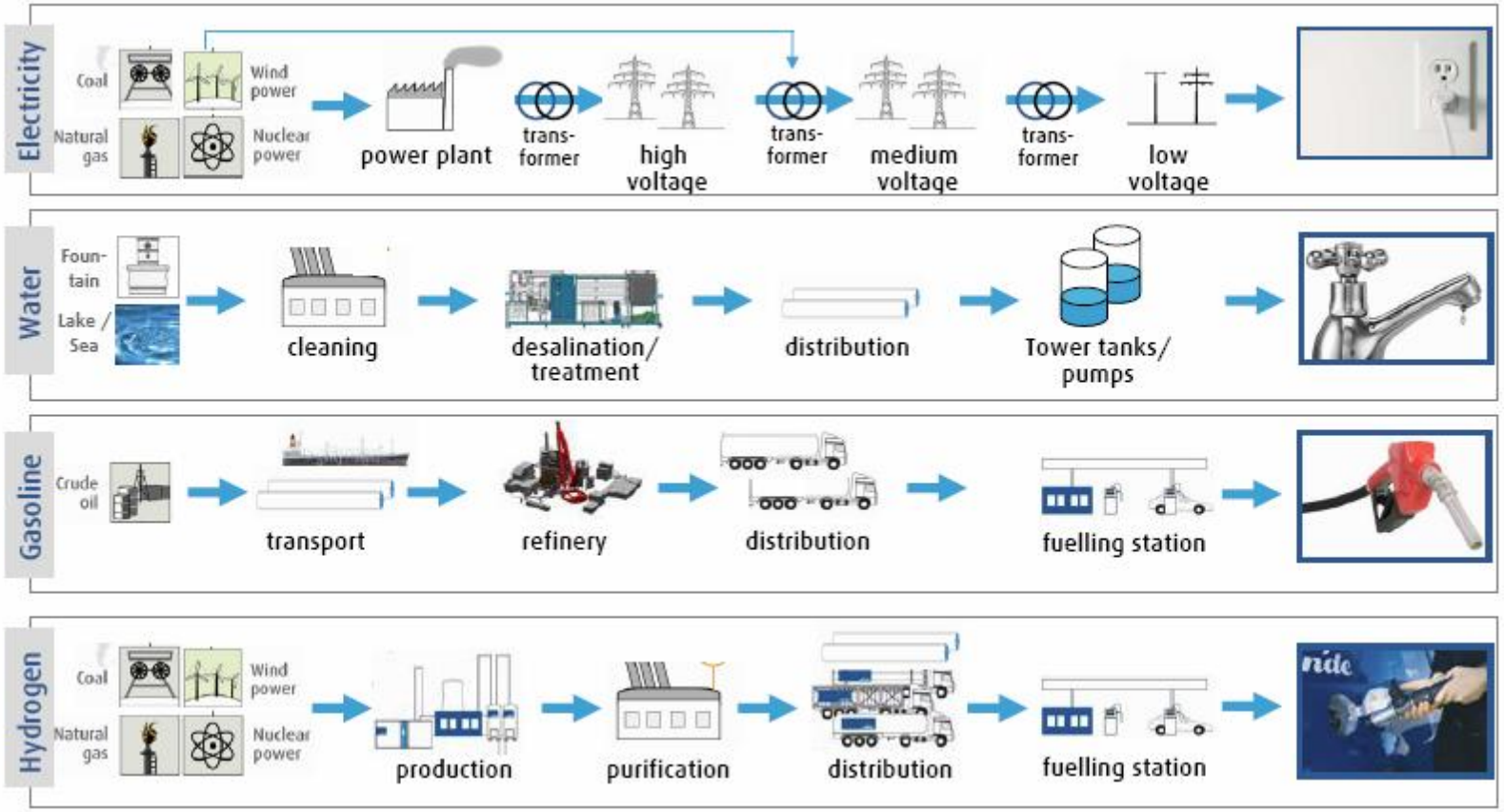
Outline

- Hydrogen Production: Applications and Demand
- Hydrogen Production Technologies:
  - Conventional
  - Fuel Choices
- Hydrogen in Transportation Applications: Current Status and Challenges
- Conclusions

Source to Final Product: Steps



Various steps in its development are involved in producing the quality and economical product.

Source: 2010 NHA Conference Proceedings - Linde

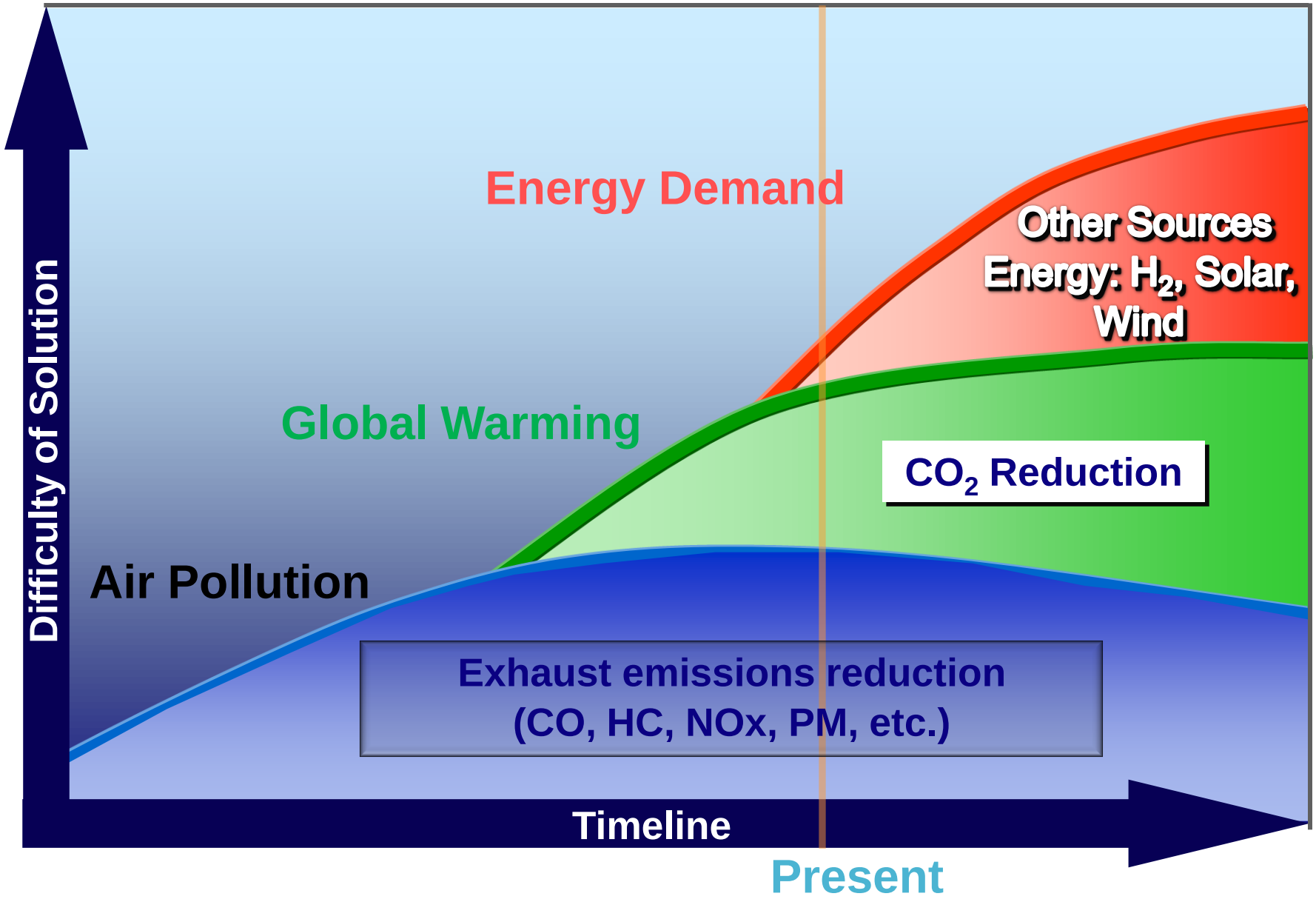
Innovation Over Time: Transportation Applications

100 Years Back

21st Century

Source: Wikipedia and Daimler

The Drive for Hydrogen



Source: 2010 NHA Meeting – Proceedings - Honda

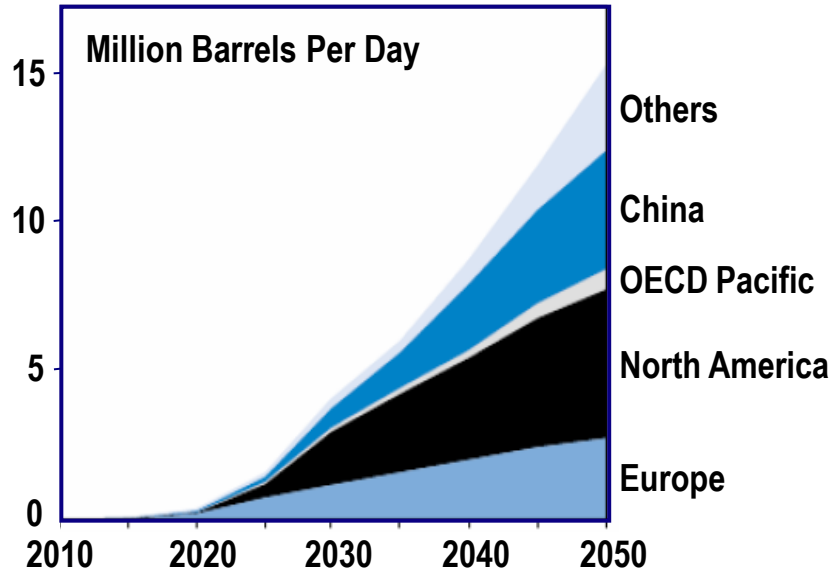
Hydrogen Production and Uses

	U.S.	World
Ammonia	38%	61%
Oil Refining	37%	23%
Methanol	10%	9%
Merchant Use	12%	4%
Other	4%	3%
Annual Production	89.3 m^3	449.3 m^3
in Billions	8.9 kg	44.9 kg

Source: Ram B. Gupta, "Hydrogen Fuel-Production, Transport and Storage," CRC Press, 2009, 611 pp.

The Opportunities …

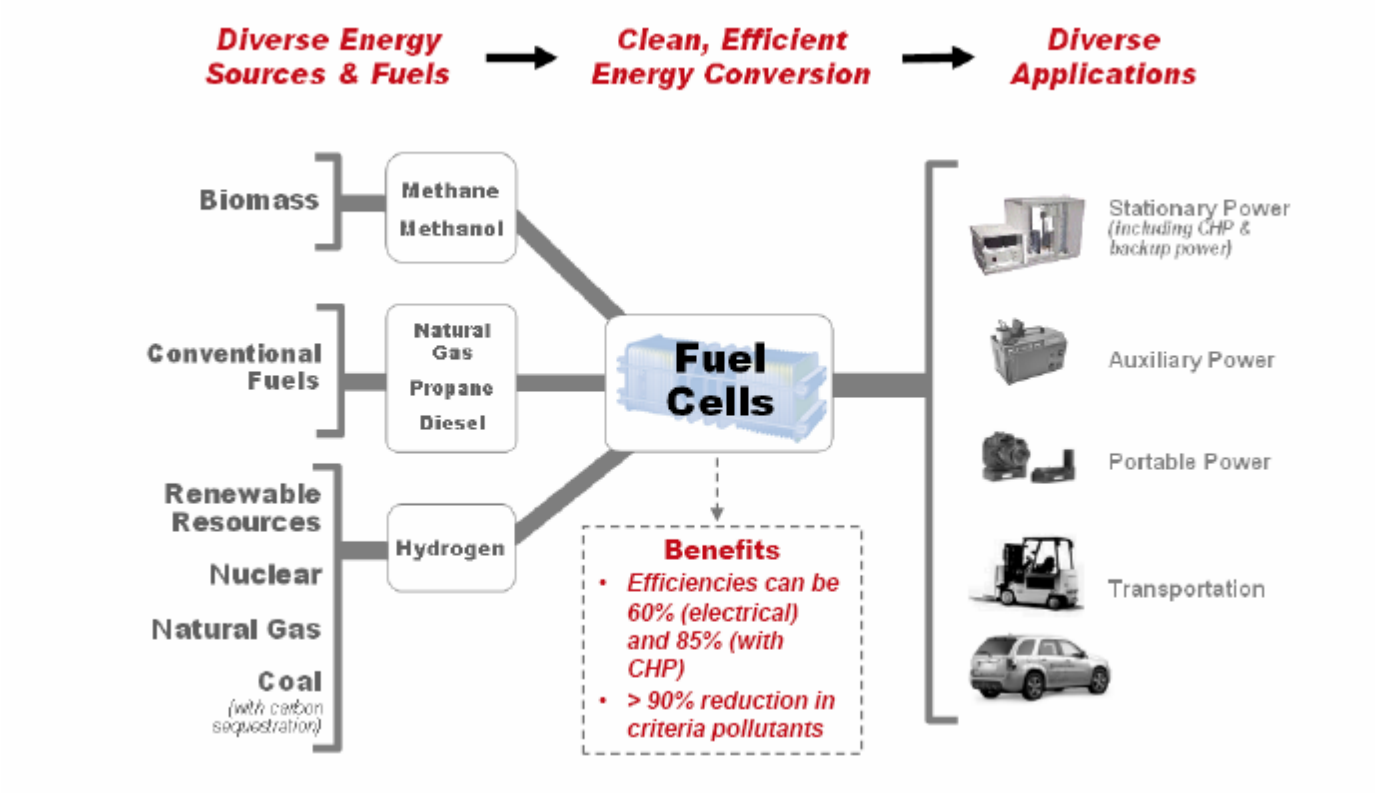
Future Hydrogen Demand, Potentially as Transportation Fuel



Size:	15 MM BOPD by 2050
Growth:	Uptake from 2020 30% of market by 2050
End-Use:	H_2 ICE and FCVs
Feedstock:	Various

Source: *"Prospects for Hydrogen and Fuel Cells" IEA (2005)*

Clean Energy Devices (Fuel Cells): Multiple Applications



Hydrogen is the Choice Fuel to Produce Clean Power More Efficiently

Source: DoE Energy Efficiency Website

Hydrogen Production Technologies: Approaches

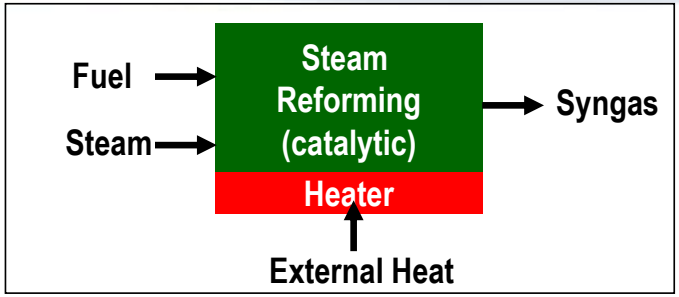
- Conventional:
  - Natural Gas reforming
  - Fossil Fuels: Oil and Gas processing
- Renewable Sources:
  - Water: Electrolysis
  - Ethanol; Biomass/Sugar; Grass
- Coal
- New Technologies: Solar and Wind based

Hydrogen Production Technologies: Conversion of Fossil Fuels

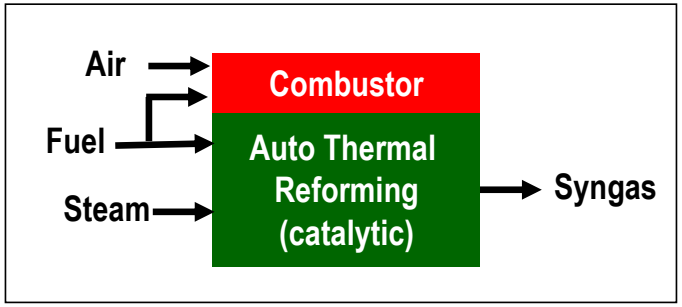
PRIMARY FUEL CONVERSION TYPE	EFFICIENCY	DESIGN COMPLEXITY
STEAM REFORMING (SR)	HIGH	HIGH
AUTO-THERMAL REFORMING (ATR)	MEDIUM	MEDIUM
PARTIAL OXIDATION (POX)	LOW	LOW

- Steam reforming is desirable for higher efficiency.
- ATR technology is desirable for mobile/on-board applications.

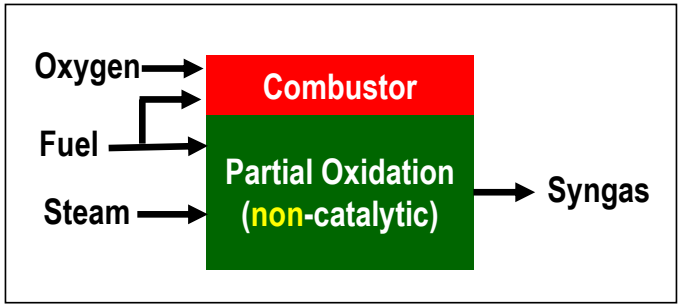
Hydrogen Production Technologies: Process Consideration



- High efficiency if waste heat available as external heat
- Process complexity due to transfer of external heat
- Syngas has no nitrogen dilution

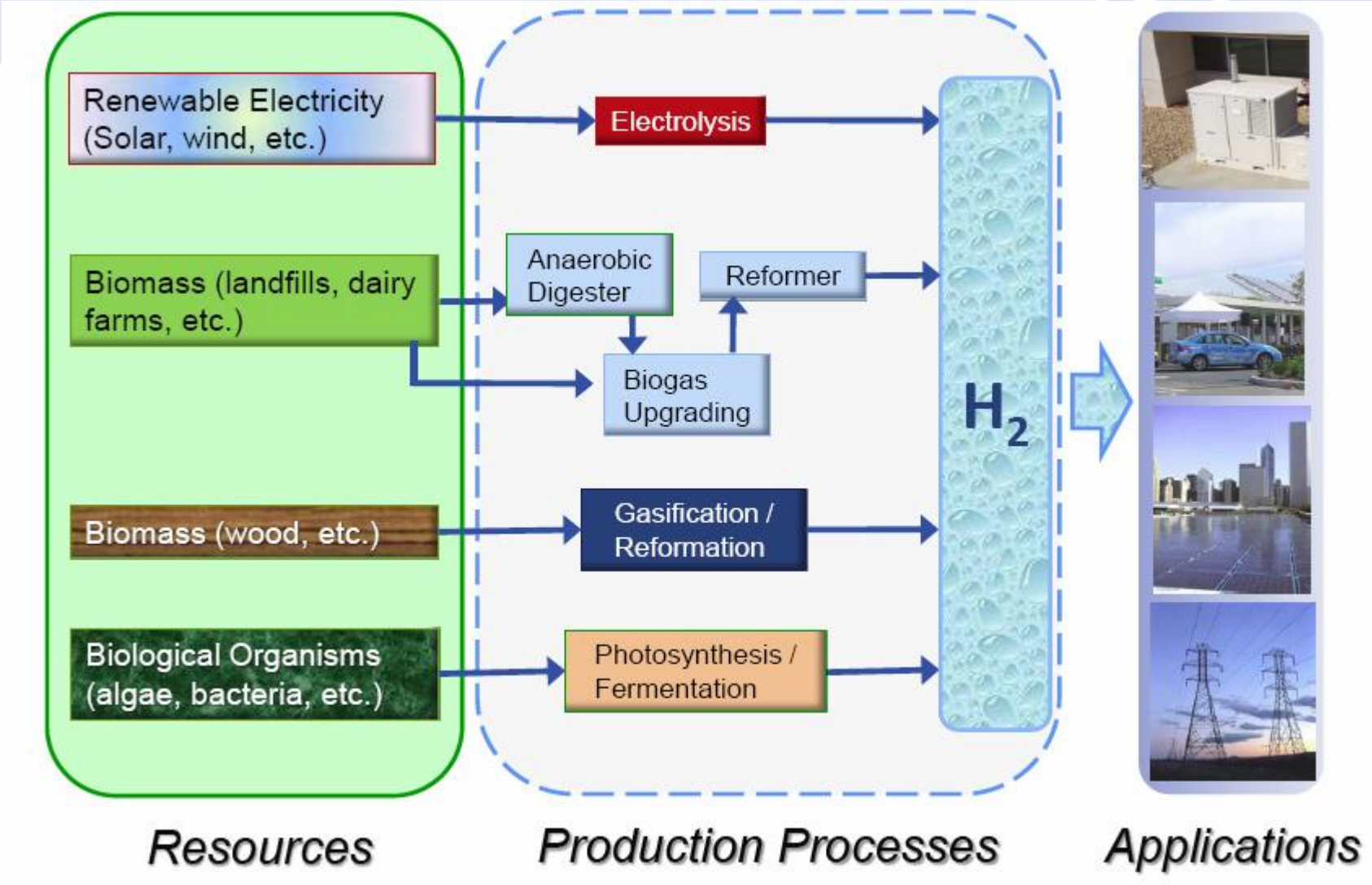


- Low efficiency due to use of part of fuel for heat supply
- Process simplicity
- Syngas has nitrogen dilution



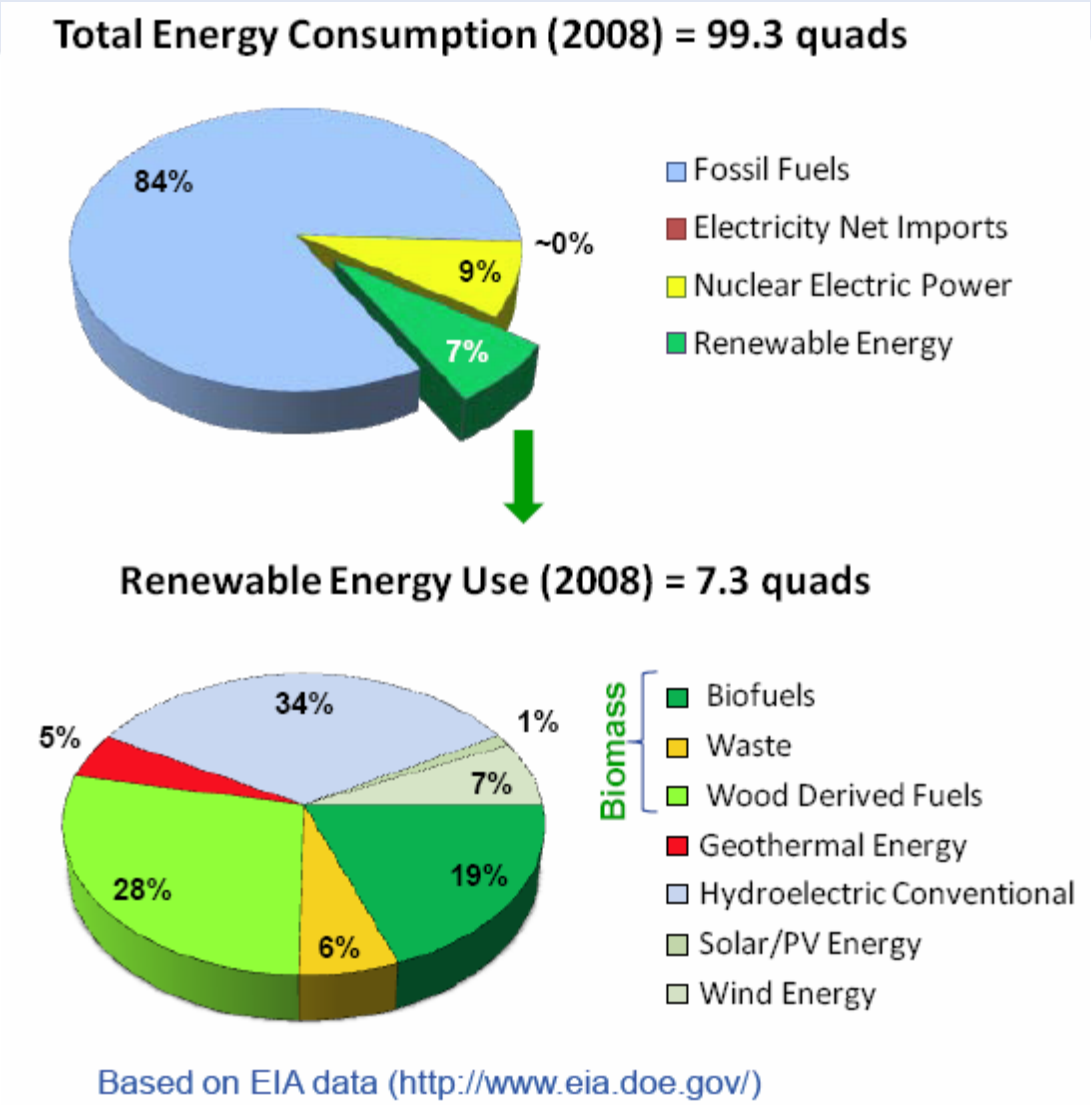
- Much higher operating temperature without catalyst
- Low efficiency due to high operating temperature
- Oxygen is expensive

Hydrogen Production from Renewable Sources



Significant Efforts Underway to Produce Hydrogen from Renewable Sources

Total Energy Consumption

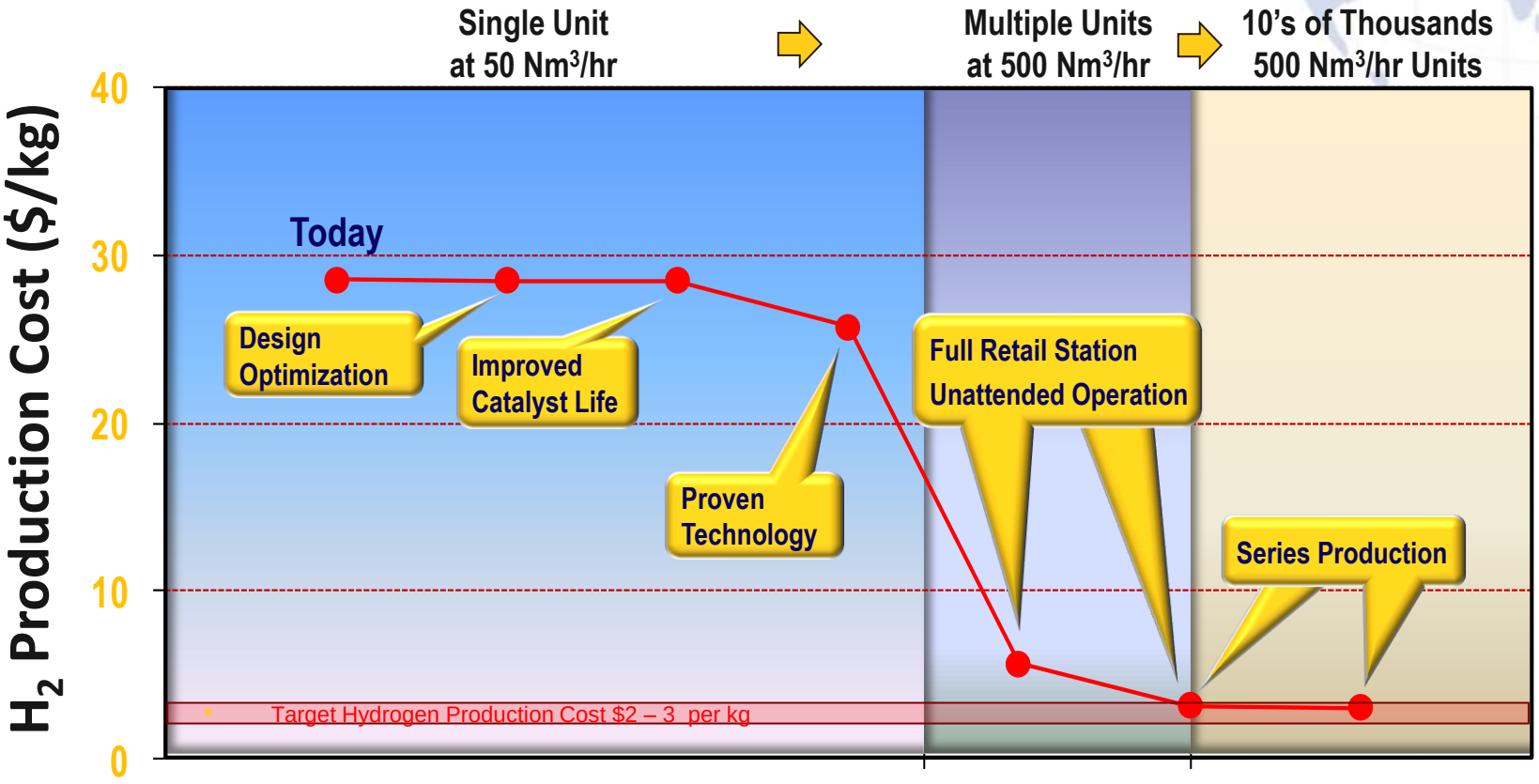


85% of Energy comes from Fossil Fuels

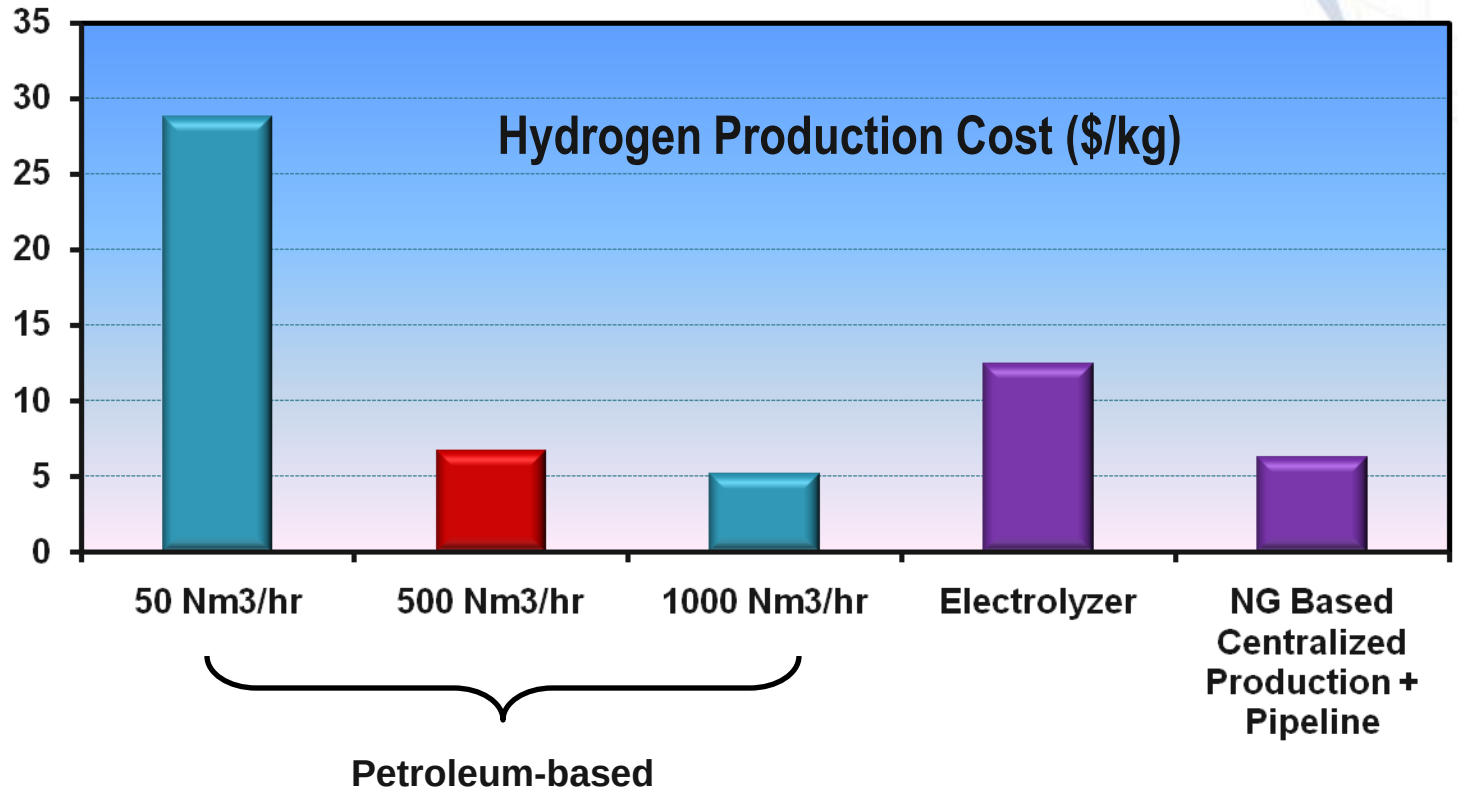
Hydrogen Production using Liquid Hydrocarbons: Transportation Applications

- H_2 production using existing petroleum infrastructure will be a potential economical option compared to other technologies.
- Need to integrate the carbon capture and storage (CCS) technologies along with hydrogen production for efficient carbon management.
- Alternate hydrogen production technologies, such as electrolysis and renewable sources, have significant technical and economical challenges (energy intensive and high capital).
- Significant progress made in the demonstration of liquid hydrocarbons to hydrogen.

Cost Reduction Path for Petroleum Based Hydrogen Filling Station



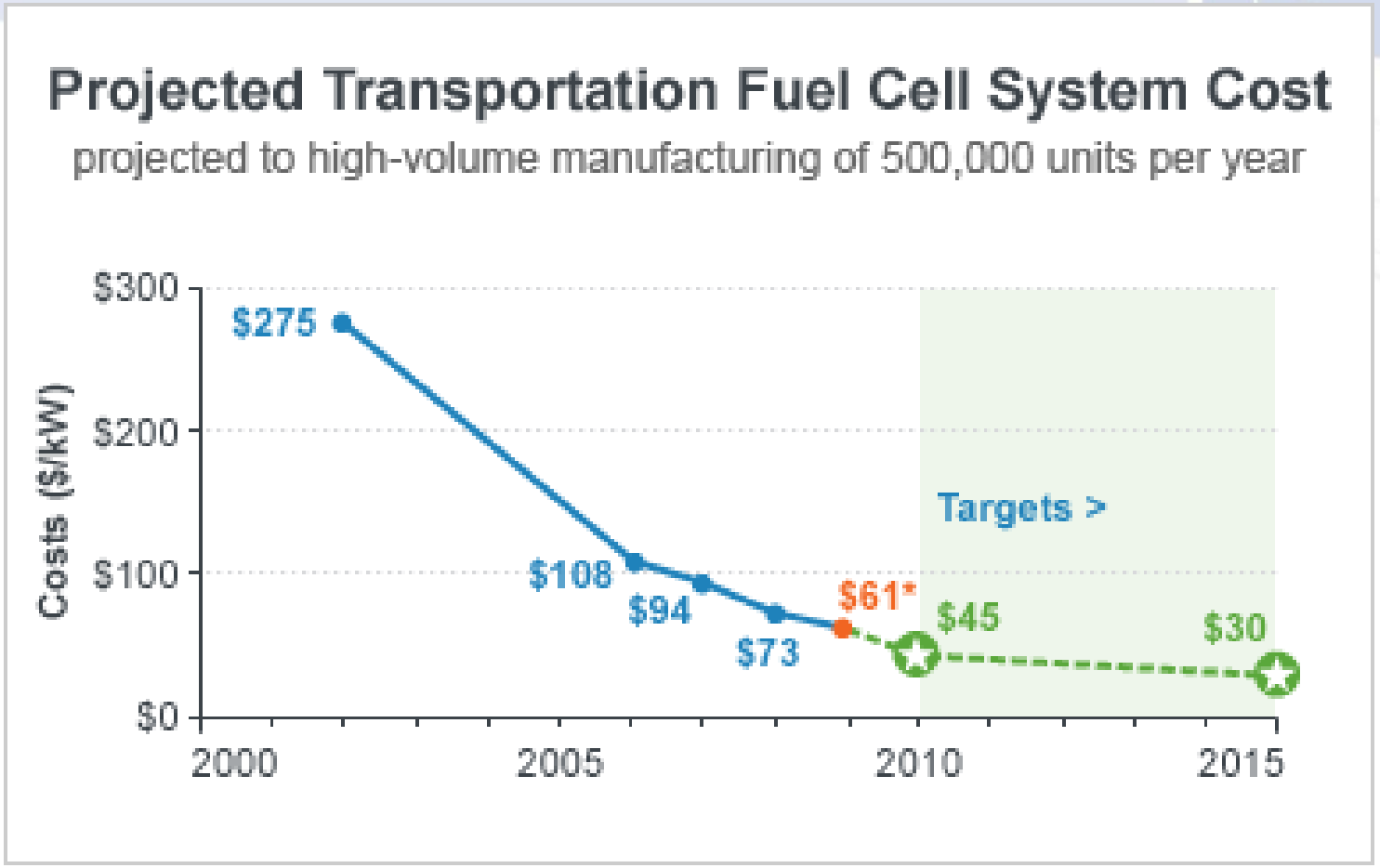
Cost of Hydrogen with Production Size and Comparison with Alternatives



Cost of Hydrogen: Target

- Hydrogen Cost Target:
  - Reduce the cost of H_2 to $2.00 - $3.00/gge dispensed at the pump. The target is independent of the hydrogen production technology.
- The above target is set by DoE and is being considered by all hydrogen and fuel cell developers in order to be commercially competitive and ensure mass deployment.

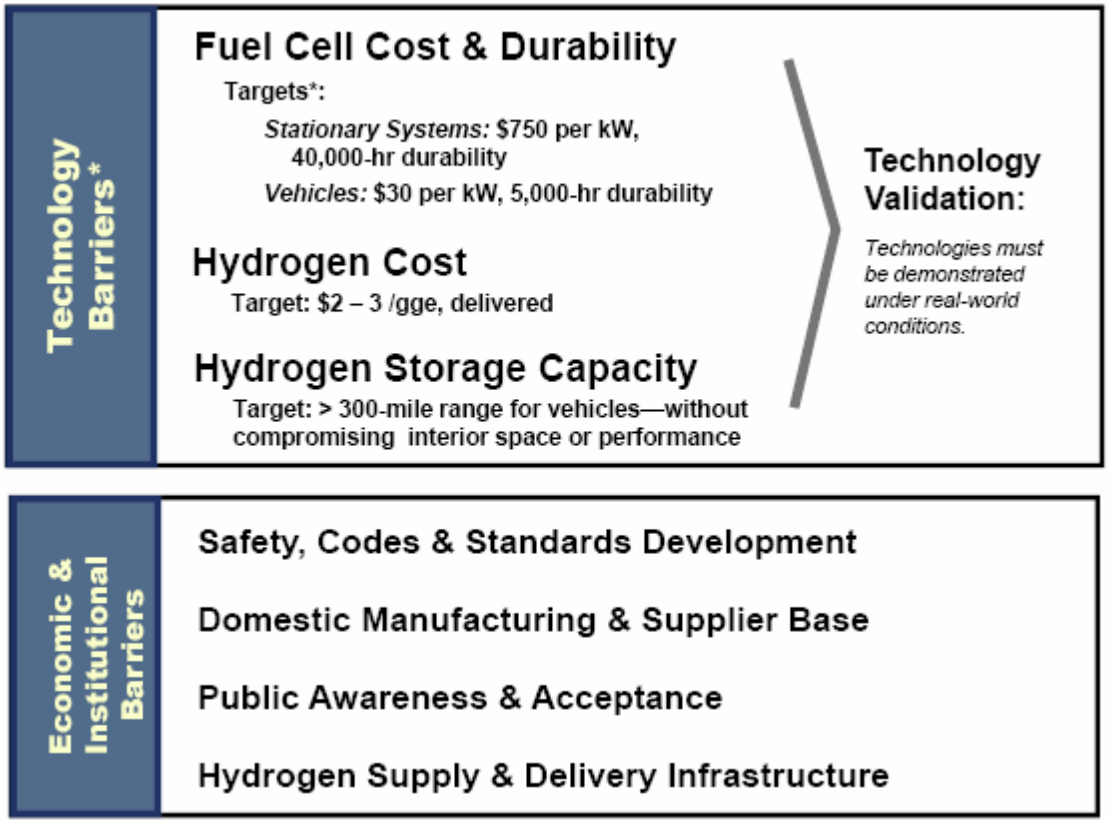
Fuel Cell System Cost: Transportation Applications



Significant progress in reducing the fuel cell cost.

Source: DOE Energy Efficiency and Hydrogen Website

Key Challenges: H_2 based Transportation Applications



Source: DOE Energy Efficiency and Hydrogen Website

H_2 based Fuel Cell Vehicles and Buses in U.S.: Projection

- Meeting environmental regulations will require strategies like H_2 and FCs.

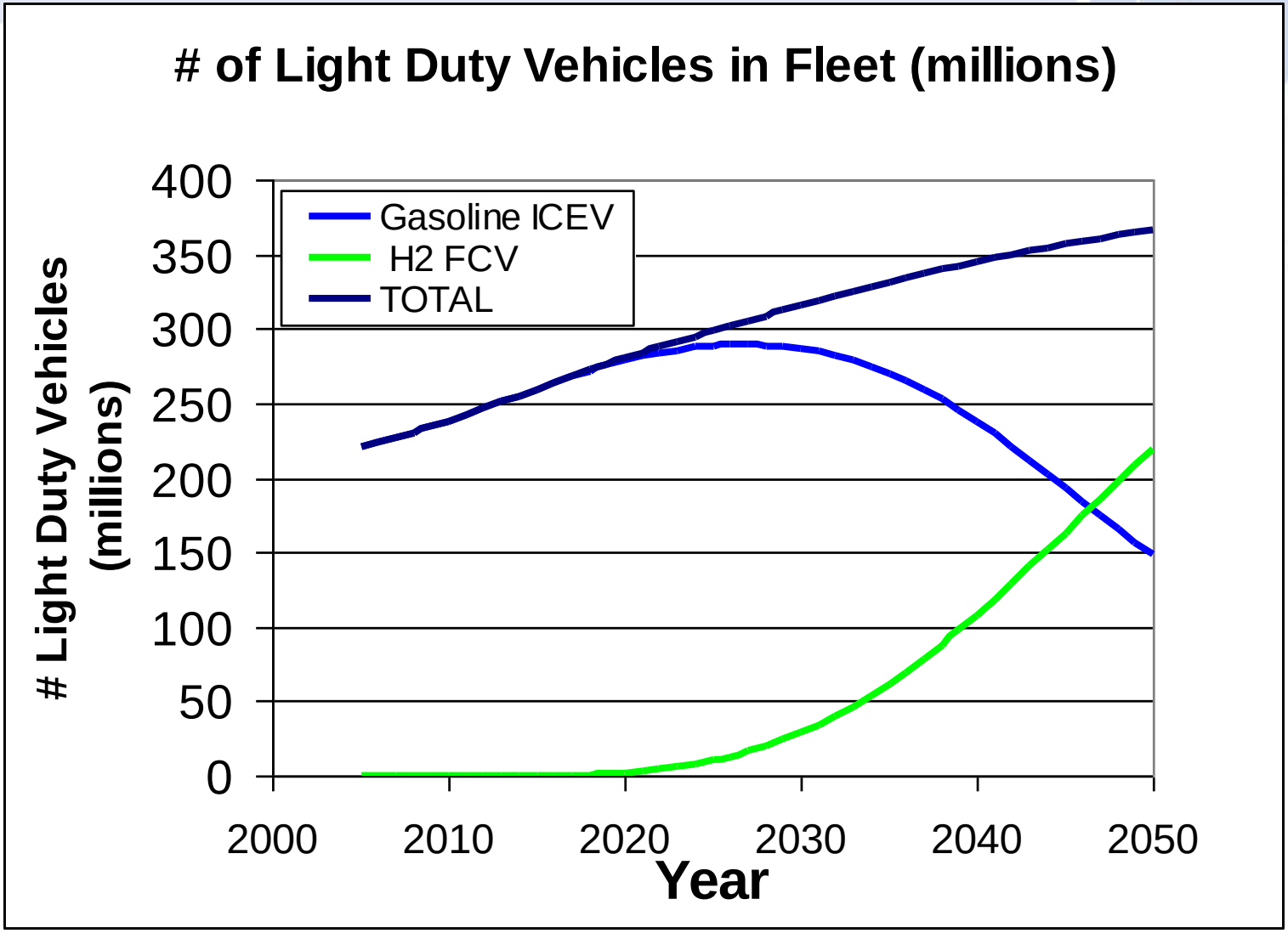
	Hundreds	Thousands	Tens of Thousands
	Through 2012	2013-2015	2016-2018
Total passenger vehicles	450	4,200	54,300

	Field Testing	Full-scale demonstration	Commercial
	Through 2011	2012-2104	2015-2017
Number of fuel cell buses	15 to 17	20 to 60	60 to 150

**Total number projected on the road at the end of each timeframe*

Source: NHA Conference May 2010

Light Duty Vehicles in U.S.: Projection



Source: DOE Annual Review Meeting Aug 2010

Significant Progress Achieved

- ICE Hybrid and Fuel Cell Hybrid vehicles were tested in 2009 under the DOE Project.
- Both vehicles have ~ 430 miles Range Capacity.
- Both vehicles will cost ~ $51 to fill the tank with gasoline (at $3.1/gal and $8/kg$H_2$.
- At $5/kg$H_2$, the cost to fill-up the tank is 50% lower for the fuel cell hybrid compared to the ICE hybrid due to increased fuel efficiency.

Conclusions

- Hydrogen production from various feedstock has been demonstrated successfully.
- Significant challenges to produce hydrogen economically, but, achievable.
- Petroleum based Hydrogen generation stations can be cost competitive with other Hydrogen supply options.

Acknowledgment

- Saudi Aramco
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Thank you!

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