HYDROGEN FUEL CELLS

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EXECUTIVE DIRECTOR - GLOBAL FUEL CELLS
GENERAL MOTORS

October 5, 2016

Will hydrogen & fuel cells will come?

PERSPECTIVE

AUTOMOBILE MANUFACTURERS SELL PERSONAL MOBILITY

PERSONAL MOBILITY SOLUTIONS HAVE ALWAYS BEEN SUBJECT TO CHANGE

1917 Last Horse Drawn Street Car

PERSPECTIVE

AUTOMOBILE MANUFACTURERS SELL MOBILITY

MOBILITY SOLUTIONS HAVE ALWAYS BEEN SUBJECT TO CHANGE

1917 Last Horse Drawn Street Car

MOBILITY CHALLENGE

BY THE NUMBERS IN EARLY 20TH CENTURY (1917)

Battery Electric

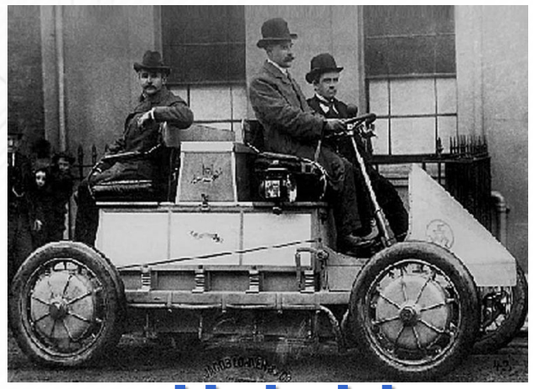
1888 Parker Electric

Steam

1903 Stanley Steamer

Internal Combustion Engine

1912 Cadillac with Internal Combustion Engine



Hybrids

1900 Ferdinand Porsche's "Mixte" Lohner Coach

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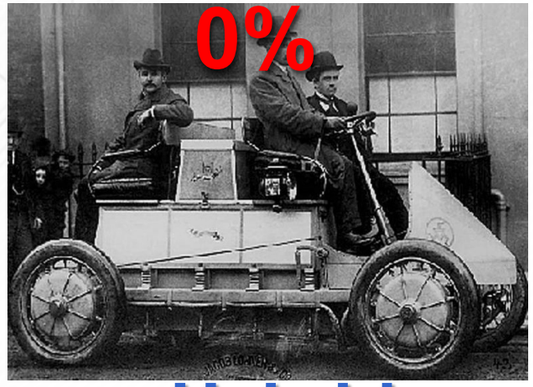

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PERSPECTIVE

FIFTY YEARS AGO

New Banking Machine

New “banking” machine was displayed for the first time at the American Bankers Association annual meeting in San Francisco, California, on October 25, 1966.

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TODAY

PayPass

Contactless way to pay - Tap and go

FIFTY YEARS AGO

Desktop Computer

Video Data Interrogator operator for California's Department of Motor Vehicles, demonstrates a key machine in the department's planned computer system at Sacramento, California, on October 20, 1966.

FIFTY YEARS AGO

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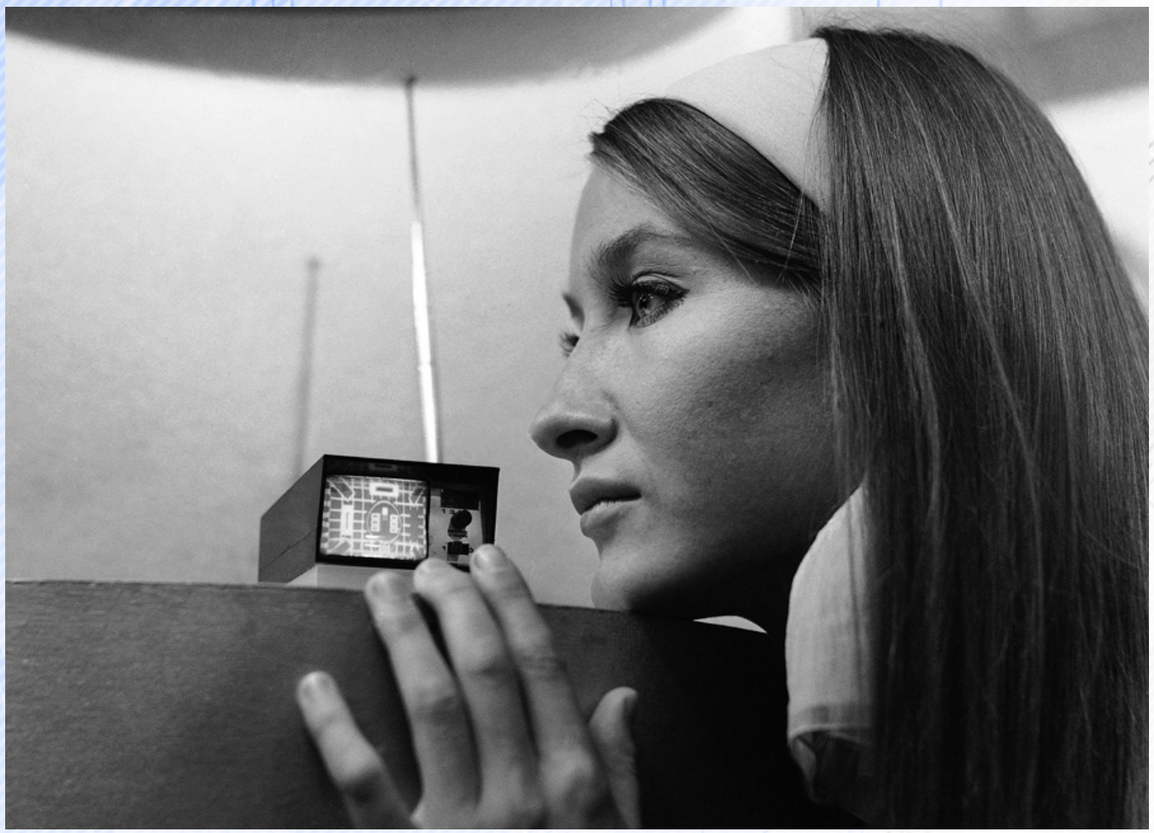
TODAY

Portable iPad

iPad with optional keyboard.

FIFTY YEARS AGO

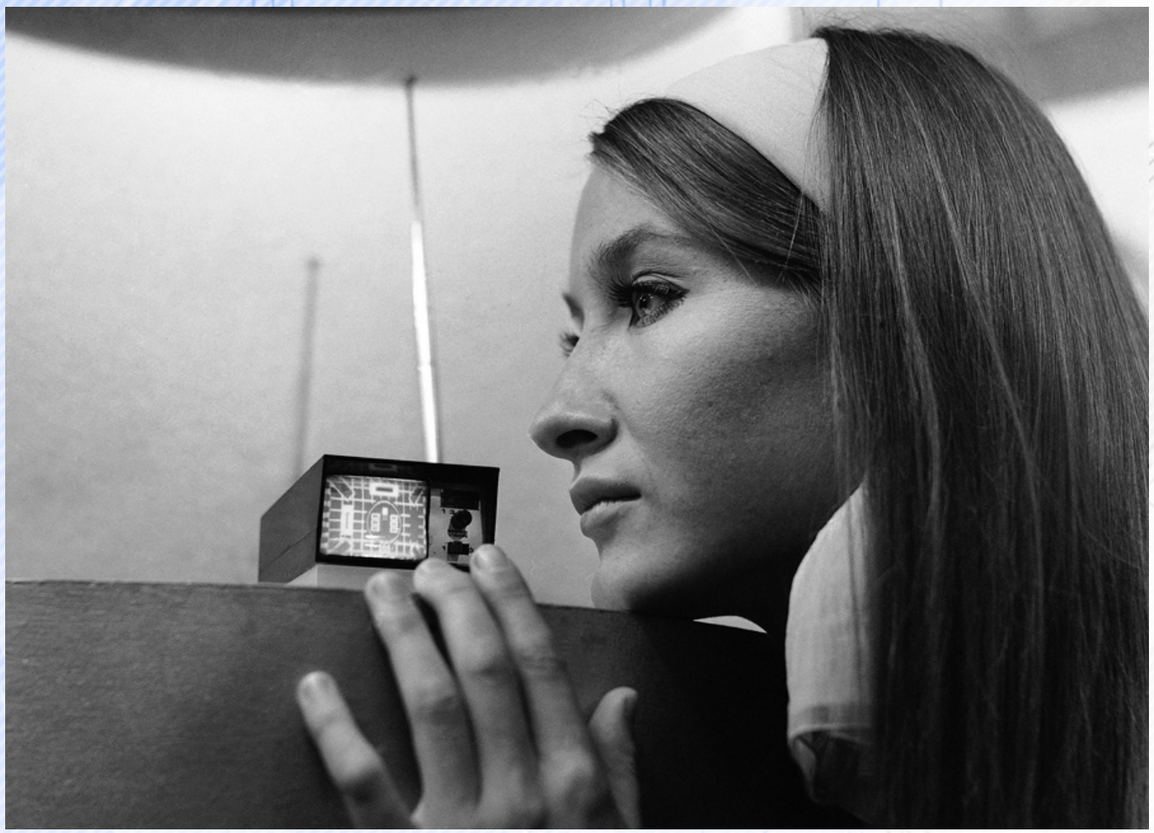
MicroTV



The Sinclair Microvision set, a pocket size television set designed by Clive Sinclair that can go anywhere and claims to be the world's smallest TV

FIFTY YEARS AGO

MicroTV



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TODAY

iPhone

The iPhone7 debuts September 2016.

FIFTY YEARS AGO

Star Trek Series Premier

The original Star Trek cast in the network television premier, September 1966.

FIFTY YEARS AGO

Star Trek Series Premier

The original Star Trek cast in the network television premier, September 1966.

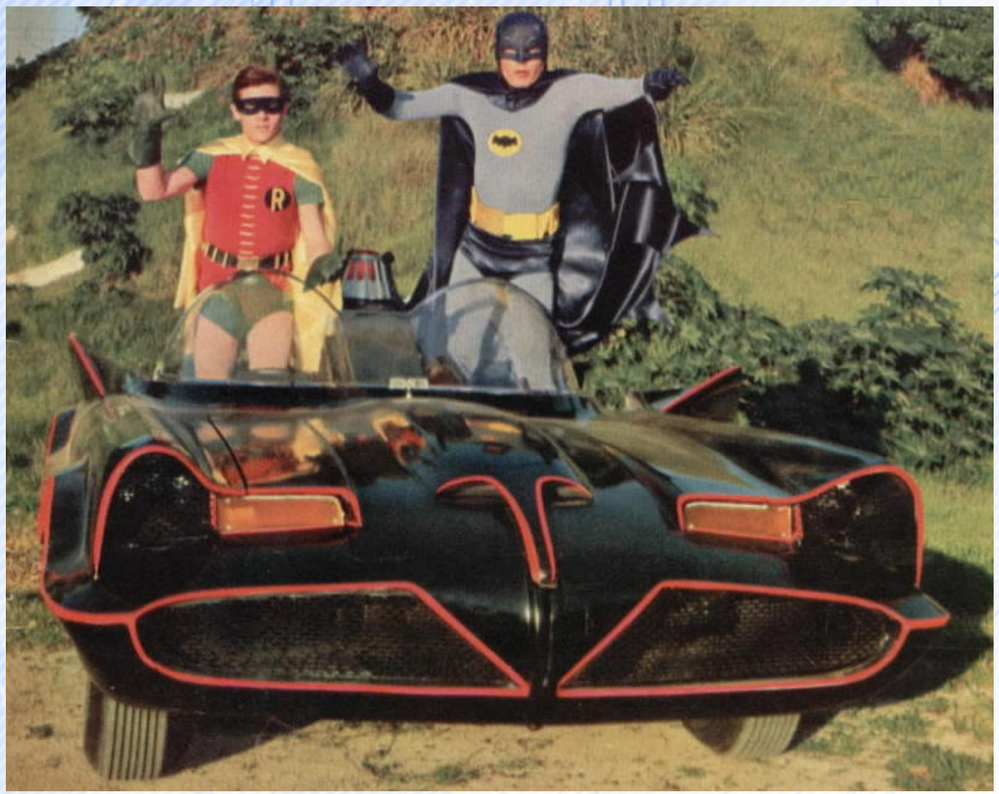
TODAY

Star Trek Rebooted

Star Trek film franchise rebooted with third sequel.
Sixth TV series launches in January 2017, on subscription TV.

FIFTY YEARS AGO

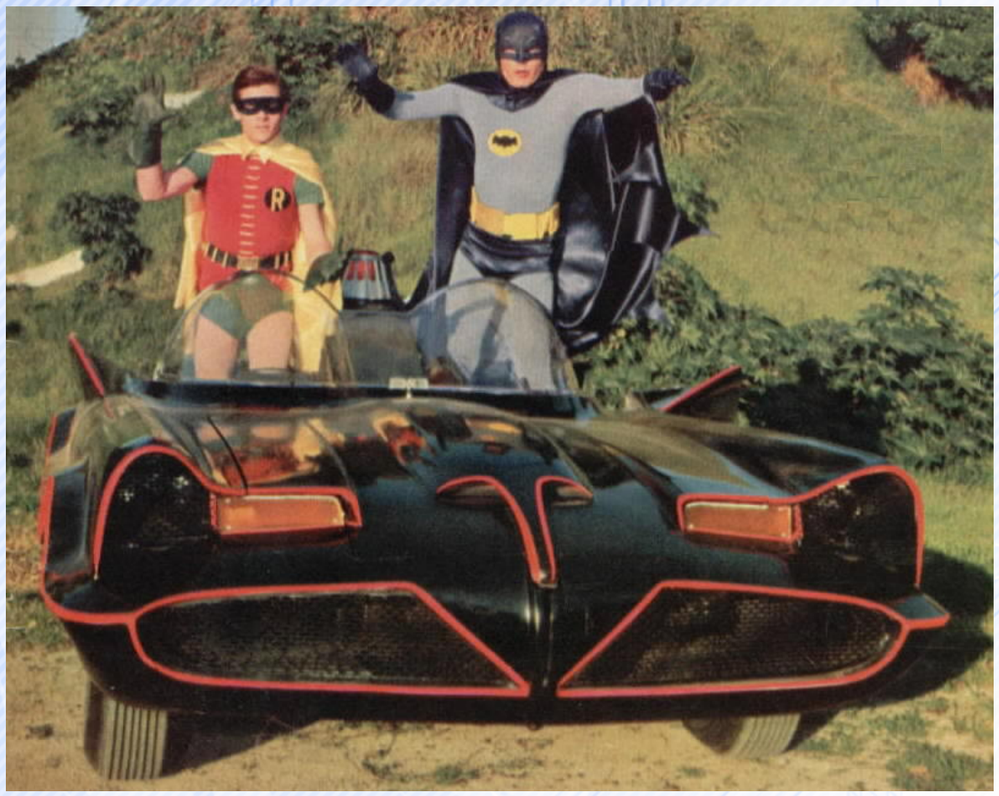
1966 Batman & Robin and the Batmobile



Adam West & Burt Ward
Tights

FIFTY YEARS AGO

1966 Batman & Robin and the Batmobile



Adam West & Burt Ward
Tights

TODAY

2016 Batman and Batmobile

Ben Affleck
Latex

FIFTY-FOUR YEARS AGO

September 12, 1962

The Challenge

FORTY-SEVEN YEARS AGO

July 20, 1969

The Landing

FIFTY YEARS AGO

World Met the first Hydrogen Fuel Cell Vehicle

Humble beginnings of the GM Electrovan

Technology Transfer from United States Space Program

FIFTY YEARS AGO

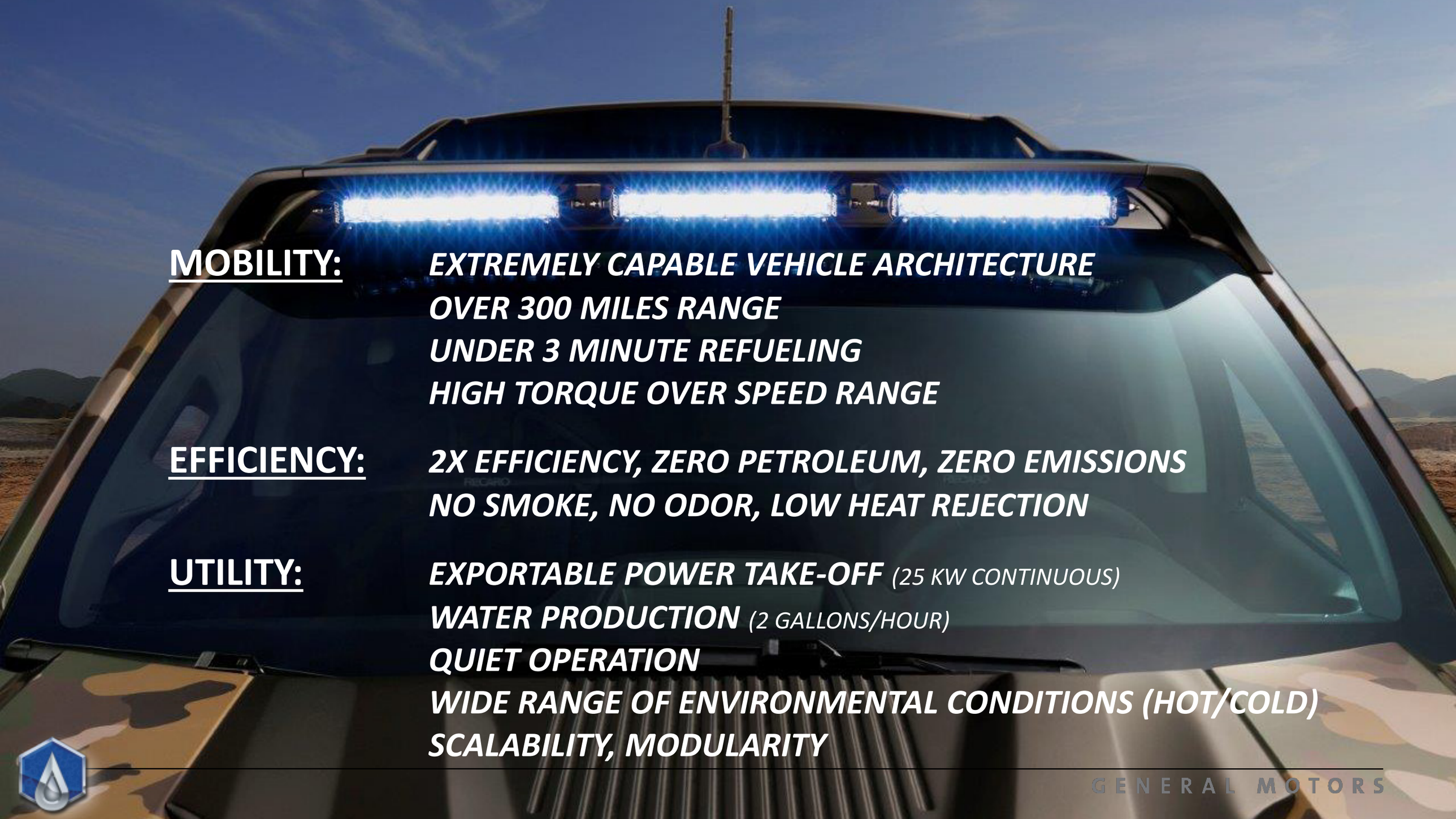
World Met the first Hydrogen Fuel Cell Vehicle

Humble beginnings of the GM Electrovan

THIS WEEK

GM Introduces Chevrolet Colorado ZH_2

Extreme-Off-Road Fuel Cell Vehicle



MOBILITY:

EXTREMELY CAPABLE VEHICLE ARCHITECTURE
OVER 300 MILES RANGE
UNDER 3 MINUTE REFUELING
HIGH TORQUE OVER SPEED RANGE

EFFICIENCY:

2X EFFICIENCY, ZERO PETROLEUM, ZERO EMISSIONS
NO SMOKE, NO ODOR, LOW HEAT REJECTION

UTILITY:

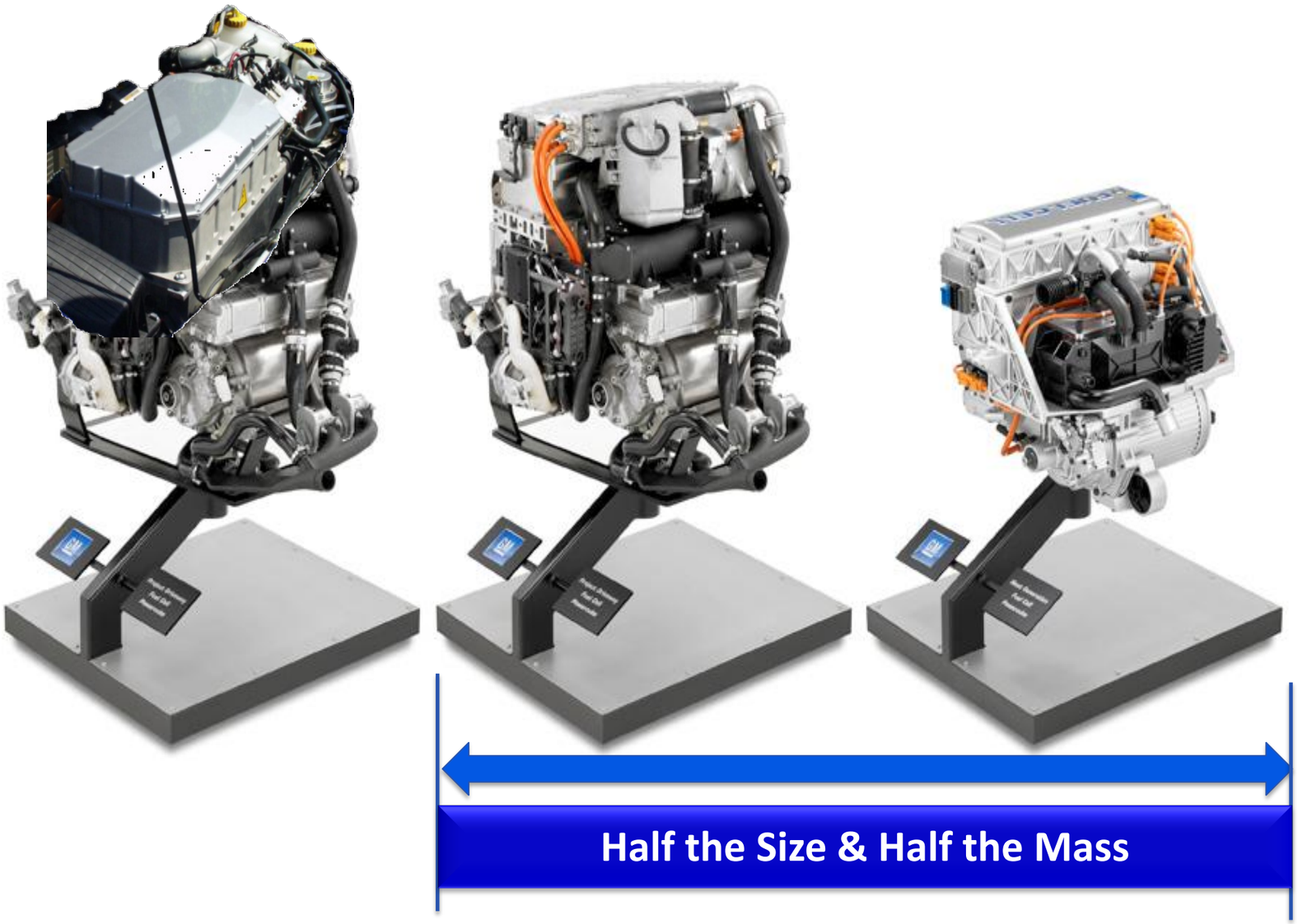
EXPORTABLE POWER TAKE-OFF *(25 KW CONTINUOUS)*
WATER PRODUCTION *(2 GALLONS/HOUR)*
QUIET OPERATION
WIDE RANGE OF ENVIRONMENTAL CONDITIONS (HOT/COLD)
SCALABILITY, MODULARITY


ZH2


GENERAL MOTORS

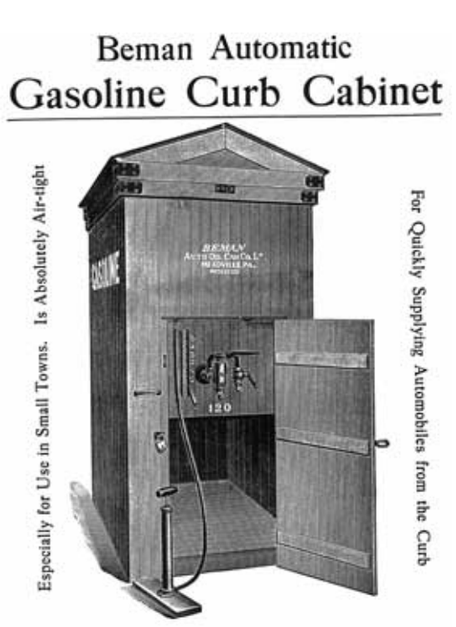

FUEL CELL
GENERAL MOTORS

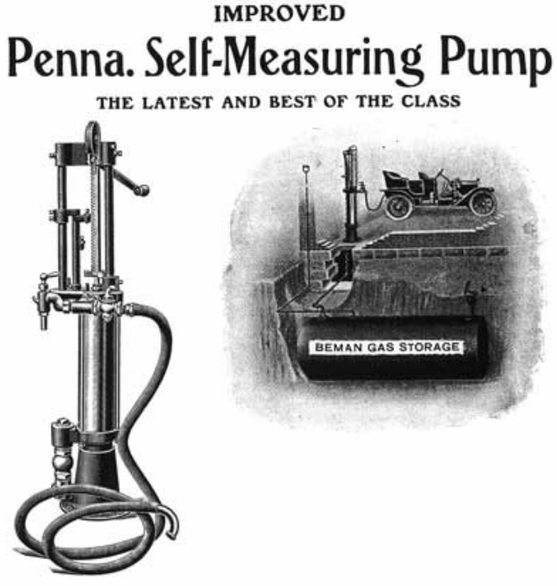
LEARNING CYCLES – REDUCING SIZE, MASS, COST



EARLY AUTOMOBILE INFRASTRUCTURE WAS ANYTHING BUT CERTAIN

Road Challenges





Refueling Infrastructure Challenges

HYDROGEN REFUELING INFRASTRUCTURE
IS IT INEVITABLE?

REFUELING/RECHARGING TIME

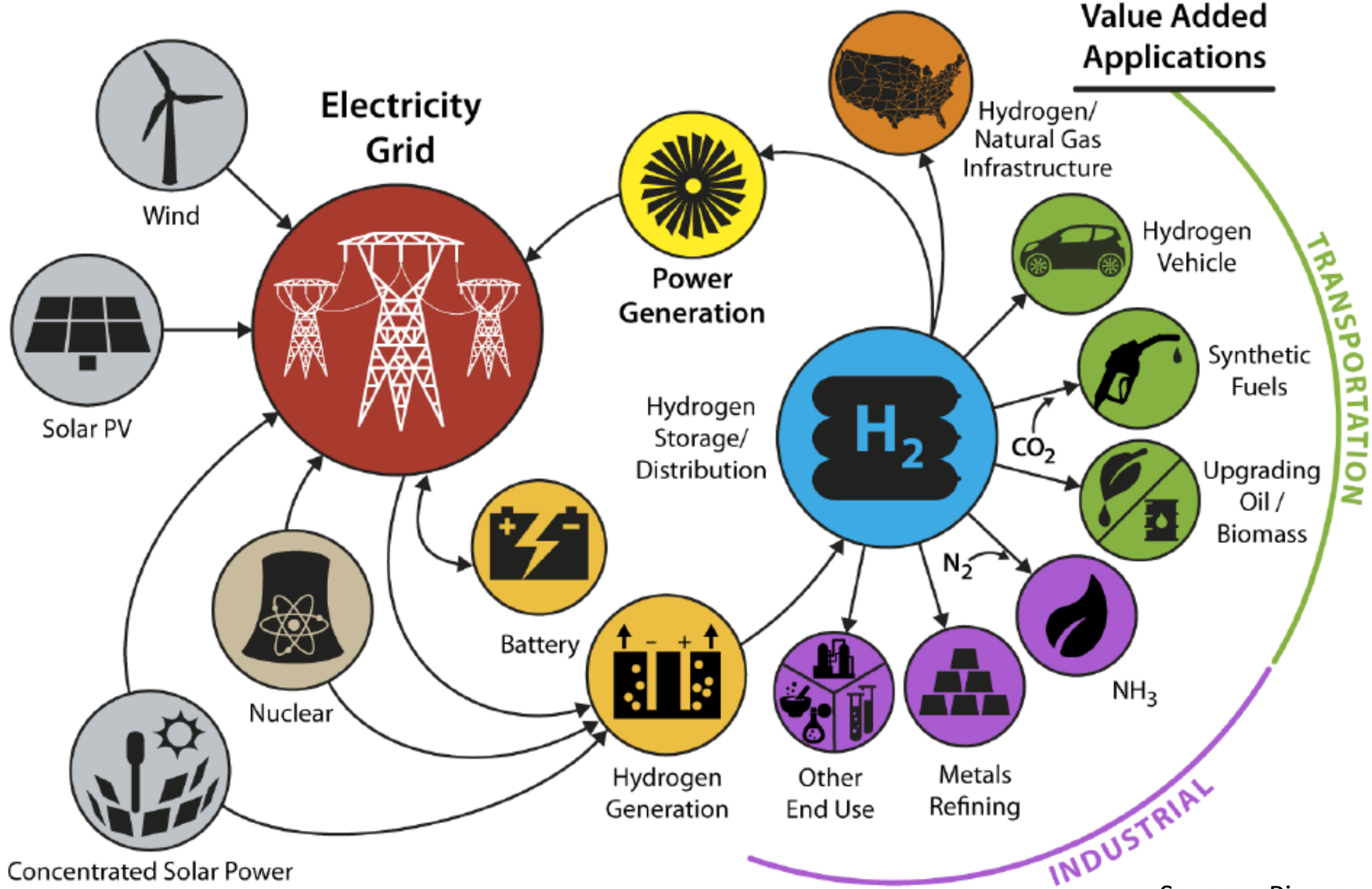
MEETING CUSTOMER NEEDS

Energy Source	Rate (miles/min)	Long-Trip % Charging Time
Gasoline	150	1-2%
Hydrogen	100	<2%
EV Supercharger	6	15%

Assumptions: Gasoline & Hydrogen Electric: 350 mile range, Battery Electric: 250 mile range

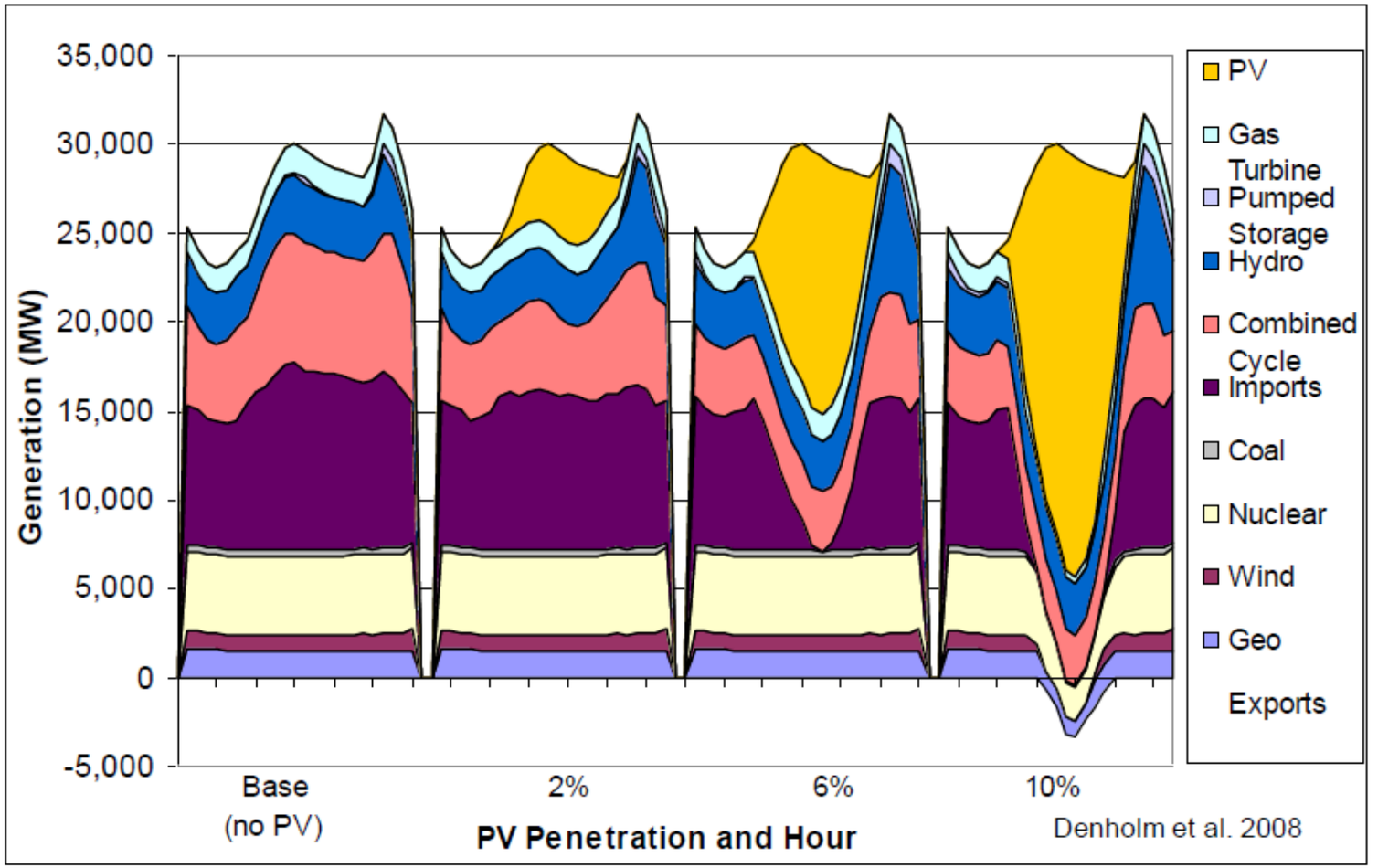
- Similar functionality to current Internal Combustion Engines
- Battery charging rates (mile/min) limited to about an order of magnitude less than H_2 refueling rates

FUTURE HYDROGEN AT SCALE "ENERGY ECOSYSTEM"



Source: Pivovar, Hydrogen at Scale NREL

SOLAR VOLTAIC RENEWABLE ENERGY (SPRING)

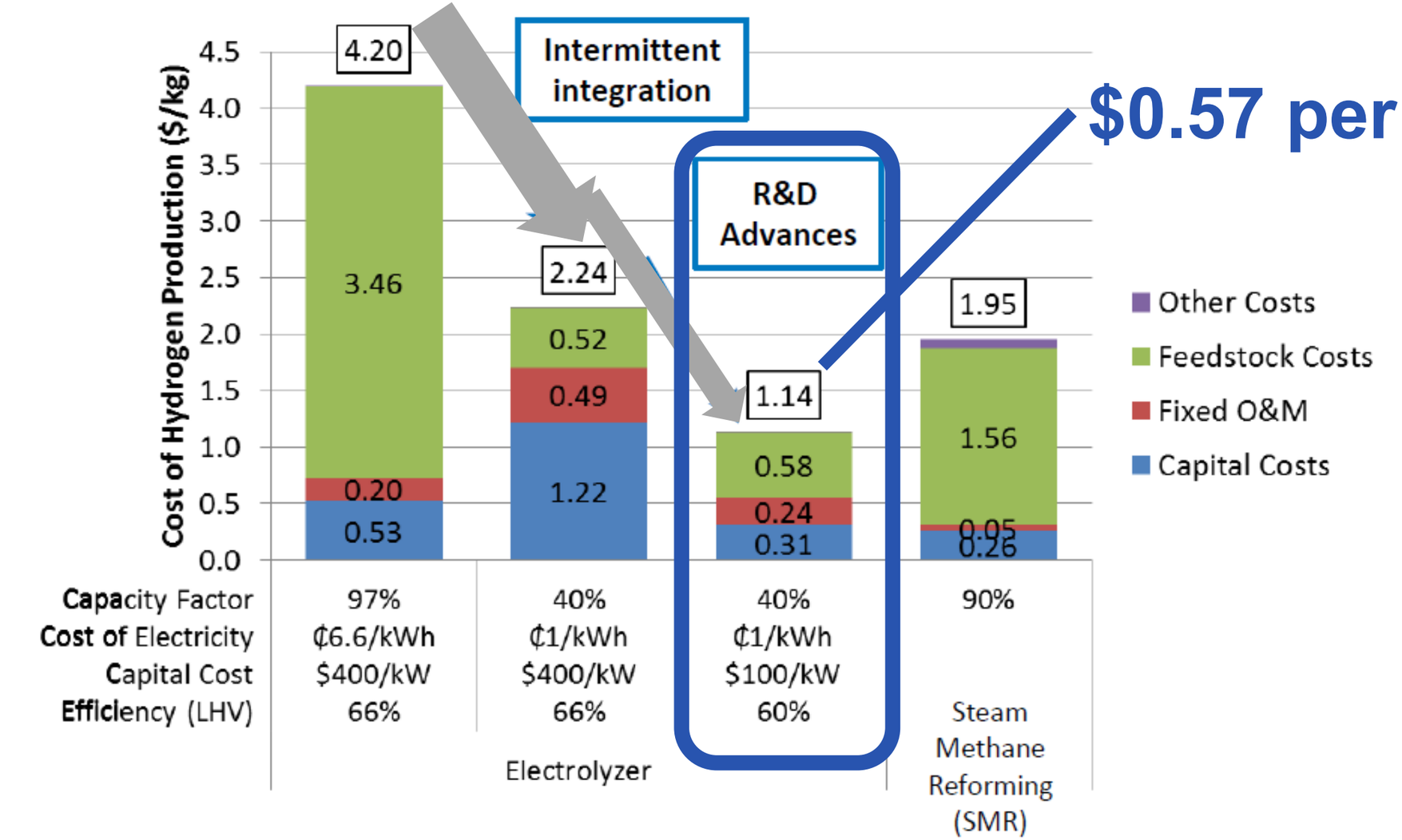


Simulated dispatch in California for a spring day with PV penetration from 0-10%

Even at low penetrations, instantaneous demand can be met by solar power

Source: Pivovar, Hydrogen at Scale NREL

IMPROVING RENEWABLE HYDROGEN ECONOMICS



H2A Analysis, Josh Eichman, NREL

Source: Pivovar, Hydrogen at Scale NREL

The question is no longer:

Will hydrogen & fuel cells will come?

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~~Will hydrogen & fuel cells will come?~~

But rather:

How quickly will they reach high volume?

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~~Will hydrogen & fuel cells will come?~~

But rather:

How quickly will they reach high volume?

How do we maintain & build momentum?

… to avoid the “fits & starts”


THANK YOU