Future Energy Transformations

Towards Hydricity Age

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EARTH COMMISSION
GLOBAL COMMONS ALLIANCE

TWI2050
The World in 2050
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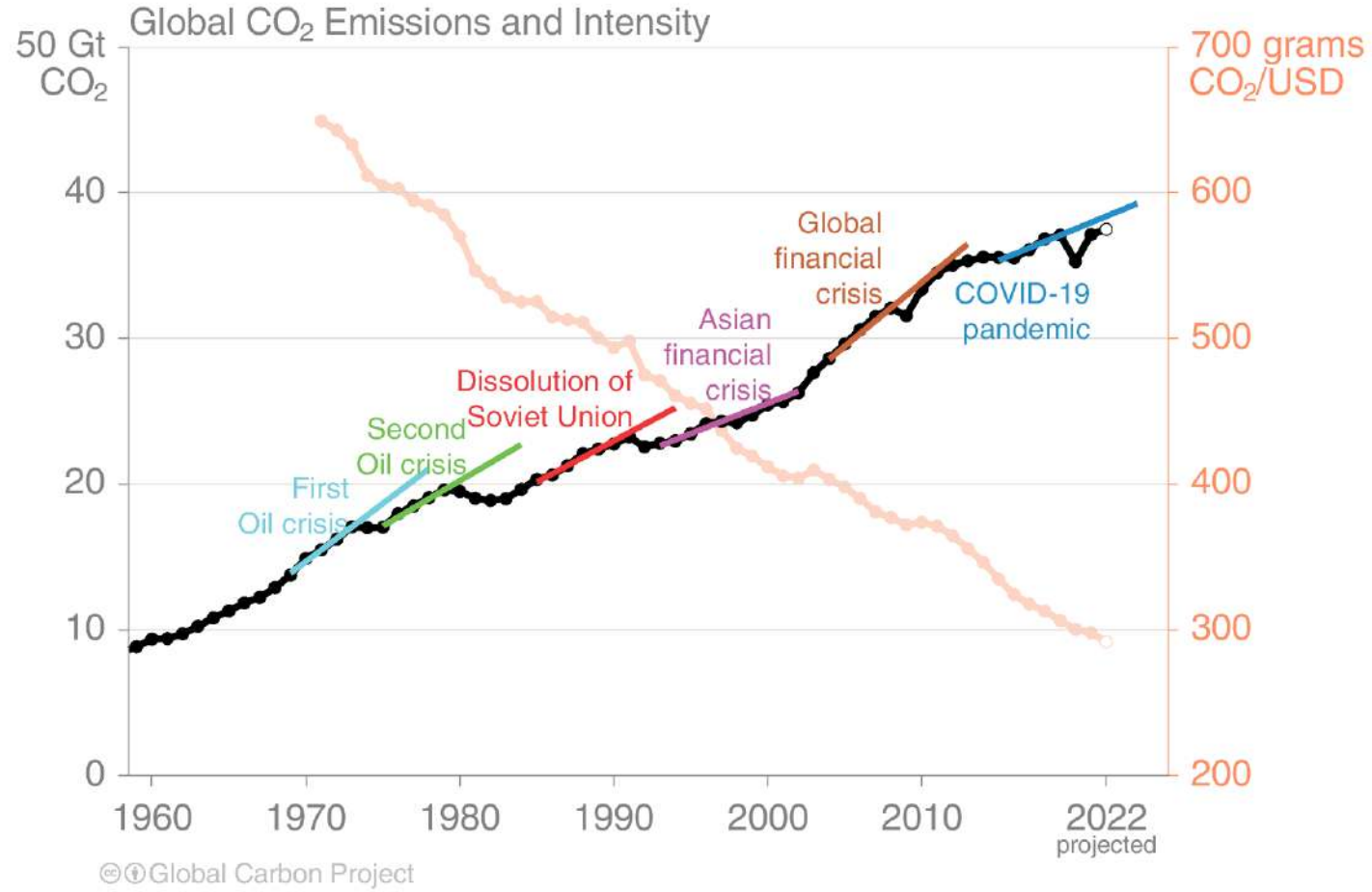
The World is at “Crossroads”

Explosive development transgressing planetary boundaries, but many are left behind

- Global economy increased 100 fold, energy 50 times and CO_2 30 times
- Temperature increase over 1^{o}C, about 8 million die due to indoor and regional air pollution
- Achievement of 2030 Agenda and Paris Agreement would bring multiple co-benefits for people and the planet

Fossil CO_2 Emission Intensity

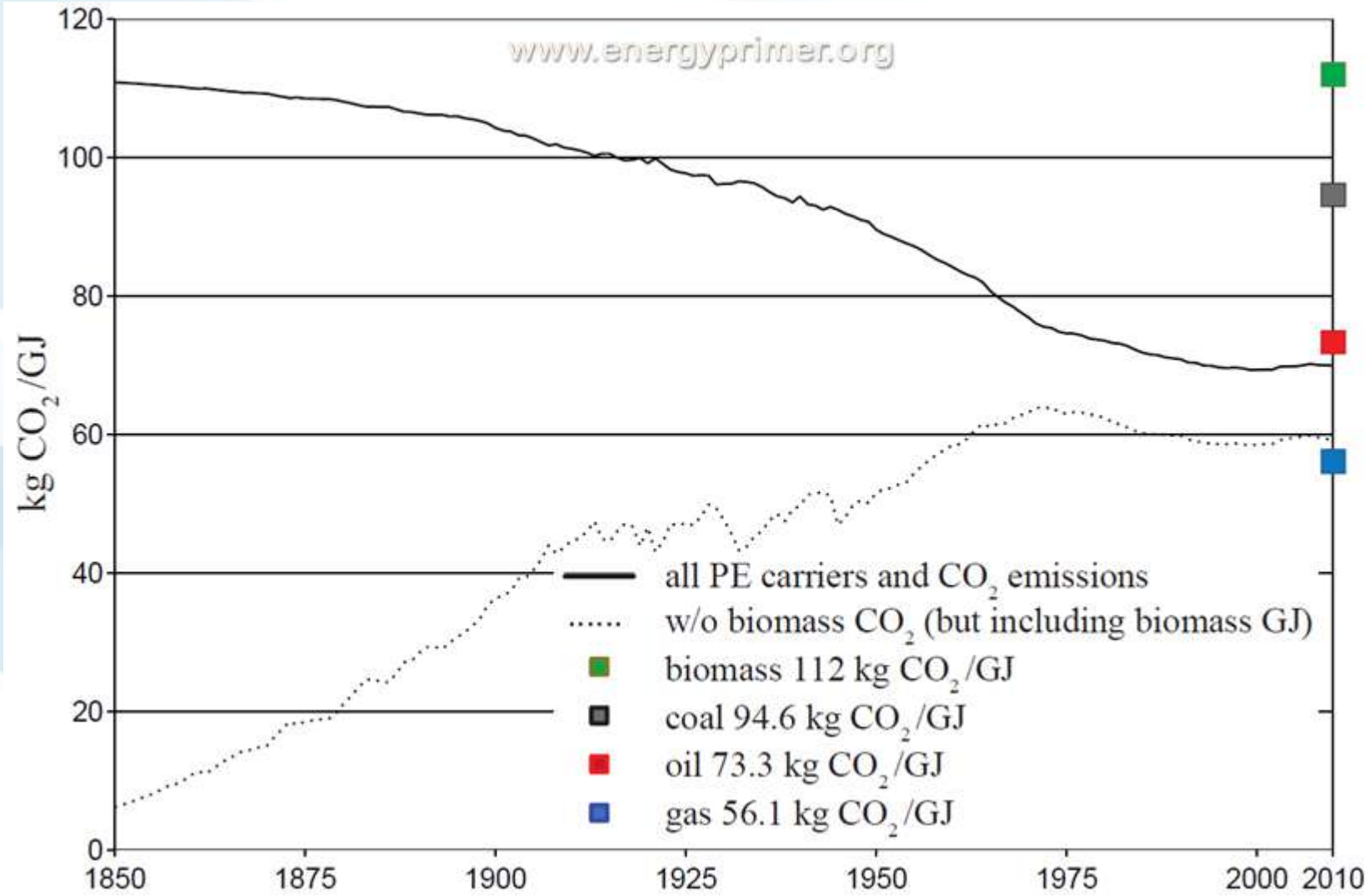
Global CO_2 emissions growth has generally resumed quickly from global crises.
Emission intensity has steadily declined but not sufficiently to offset economic growth.



Each trend line is based on the five years before the crisis and extended to five years after.
Economic activity is measured in purchasing power parity (PPP) terms in 2010 US dollars.

Source: Friedlingstein et al 2022; Global Carbon Project 2022

World - Carbon Intensity of Primary Energy

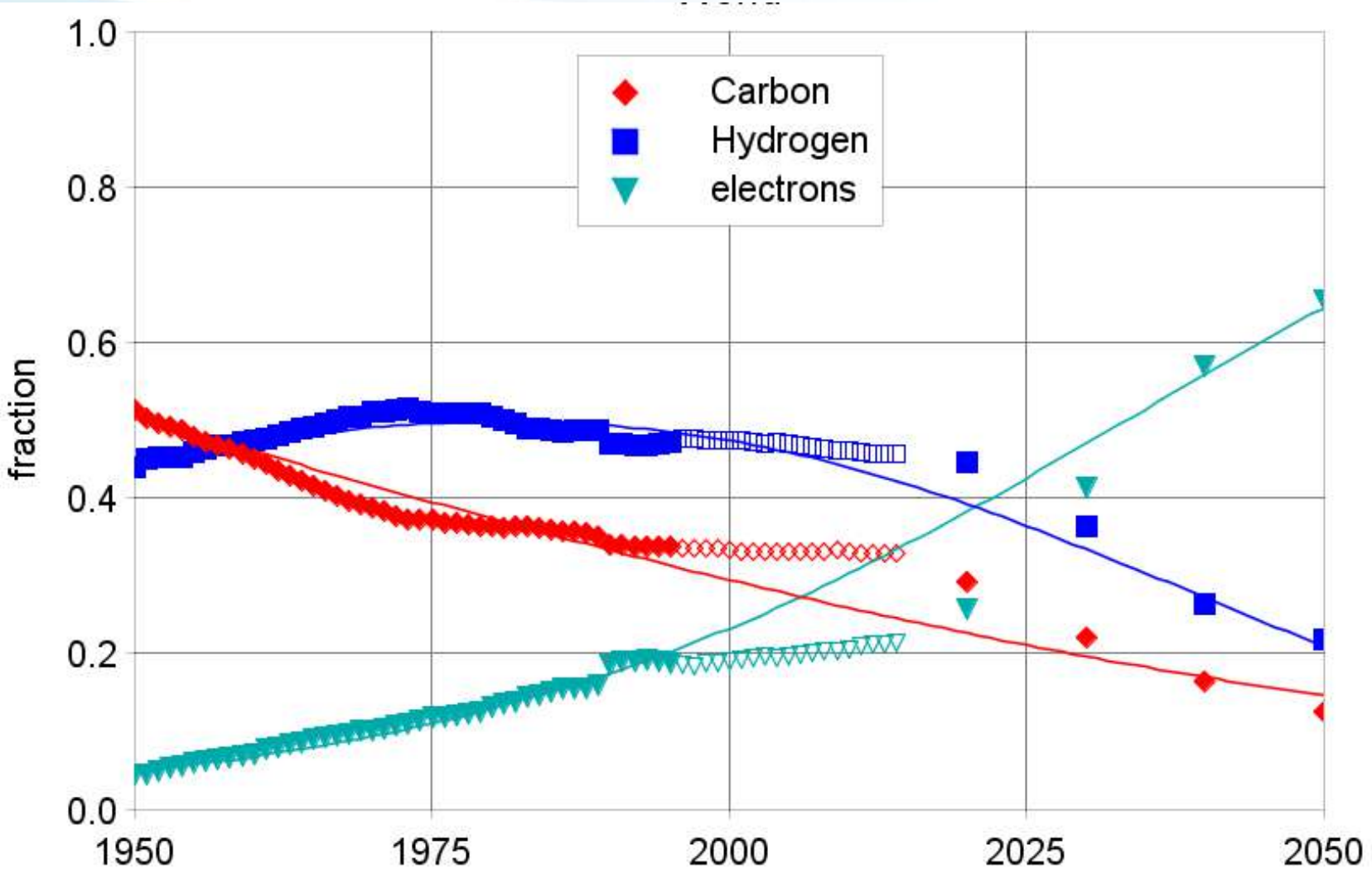


Cesare Marchetti
1927 – 2023

Hydrogen & Energy

Chemical Economy & Engineering Review, 1973

World - Carbon Intensity of Primary Energy



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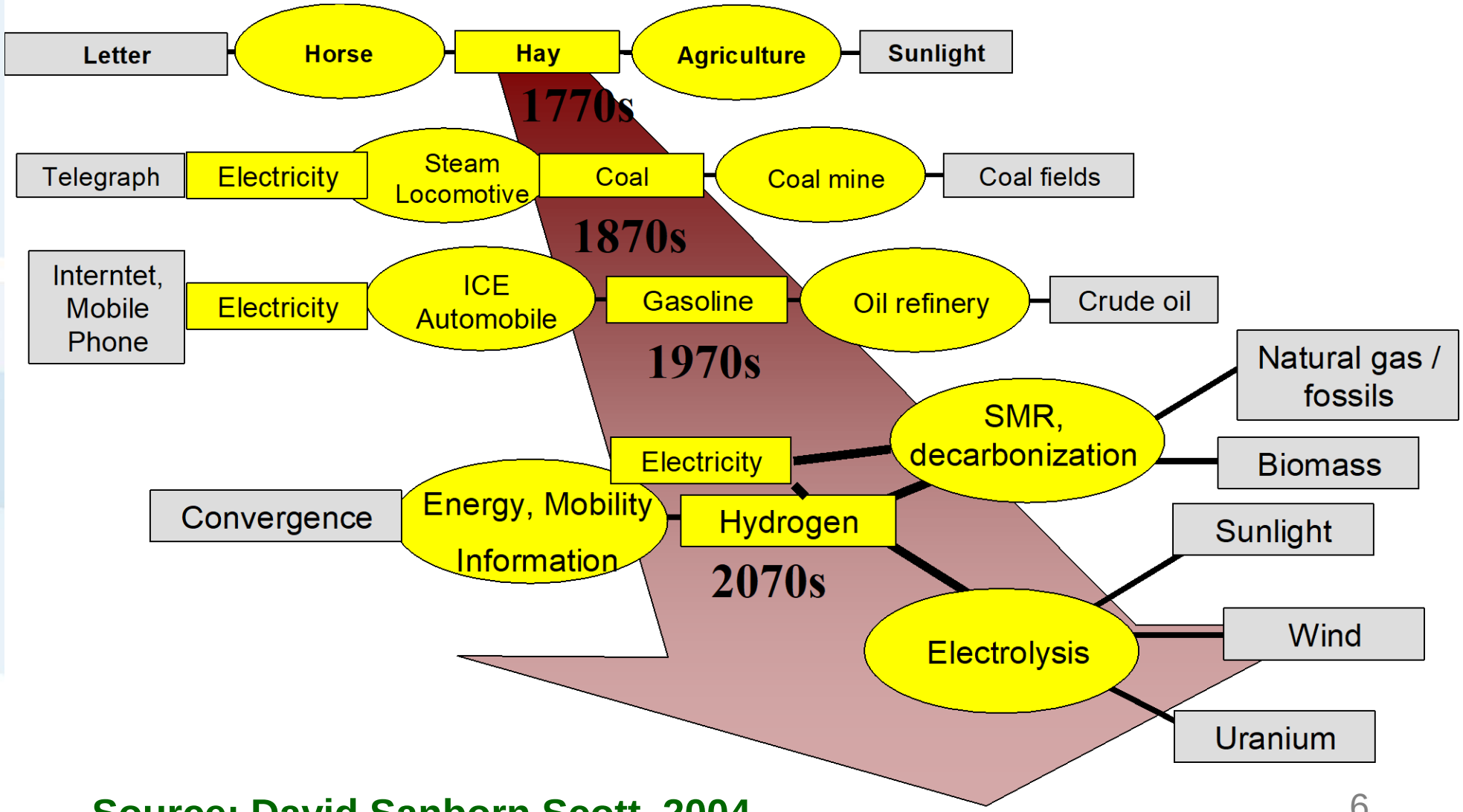
Energy System Evolution

Through Time and Possible Future



Source: David Sanborn Scott, 2004

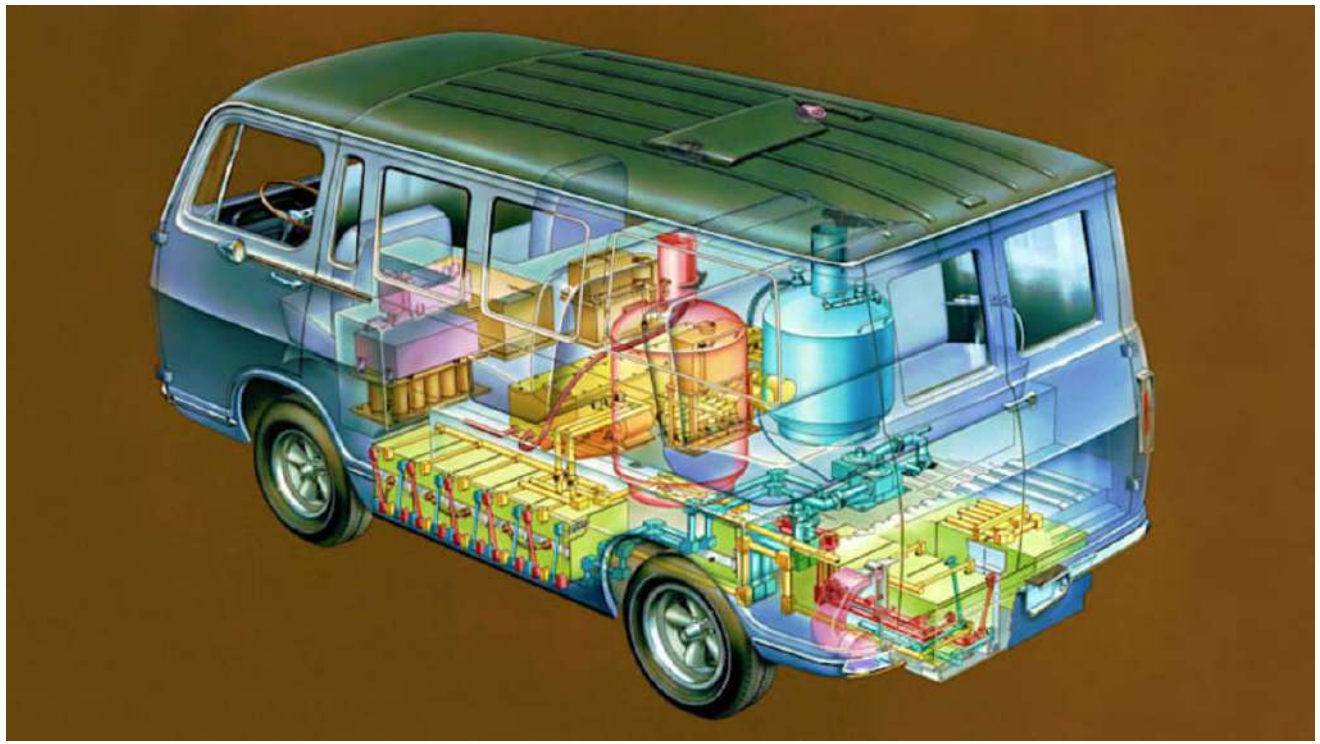
First Hydrogen Car

Swiss inventor Francois Isaac de Rivaz in 1807 designed the first 4-wheel prototype (pictured) that ran on hydrogen and oxygen gas. The hydrogen gas was contained in a balloon and the ignition was an electrical Volta starter.

https://www.automostory.com/first-hydrogen-car.htm

Fuel-Cell Electrovan

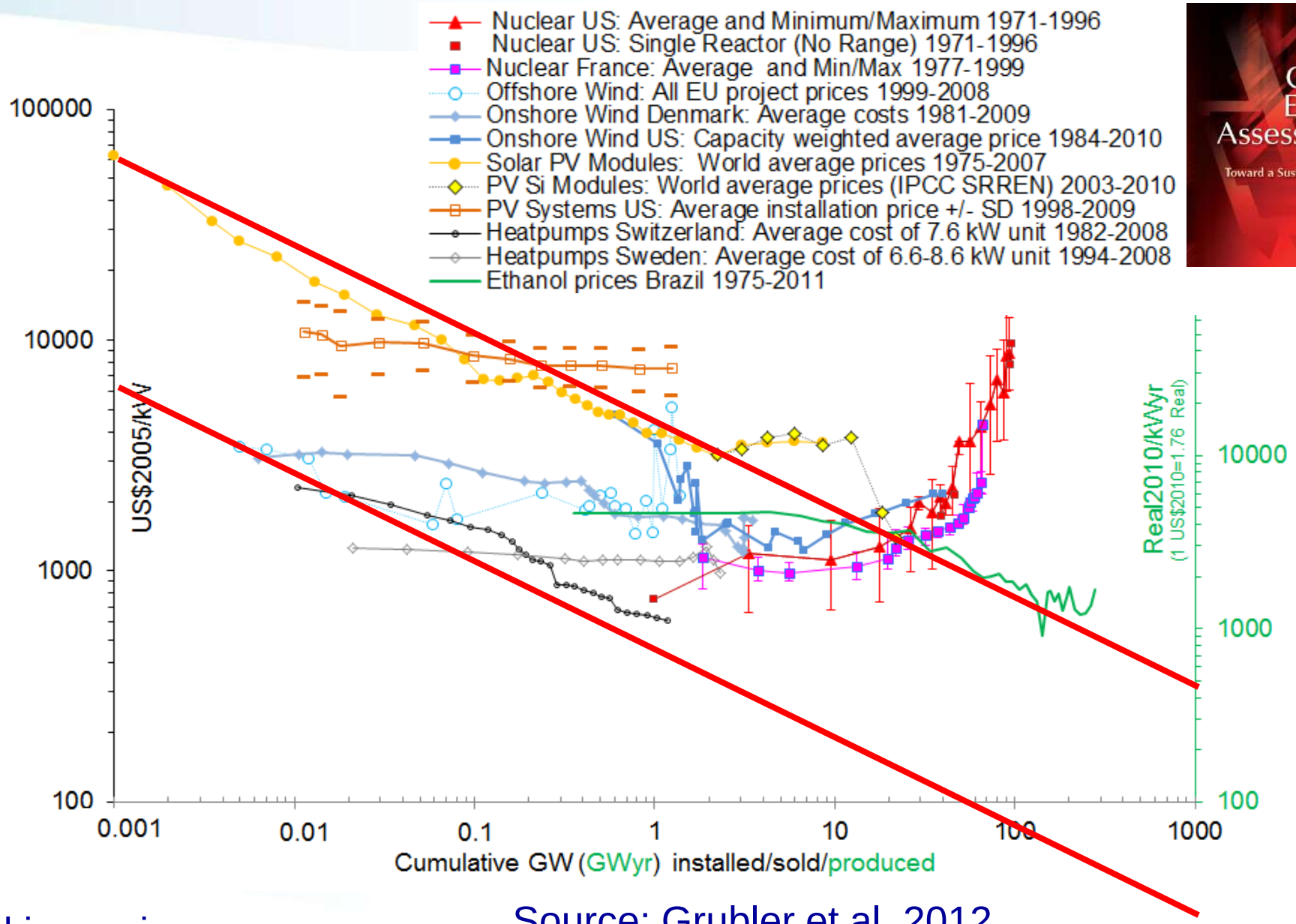
In 1966 GM G-series van was the first fuel-cell car. There was only space for two occupants and the rear of the van was filled with sliver-zinc batteries and large storage tanks for liquid oxygen and hydrogen. Impressively, the van could travel between 100 and 150 miles between fill-ups.



Uncertainty of Technological Change

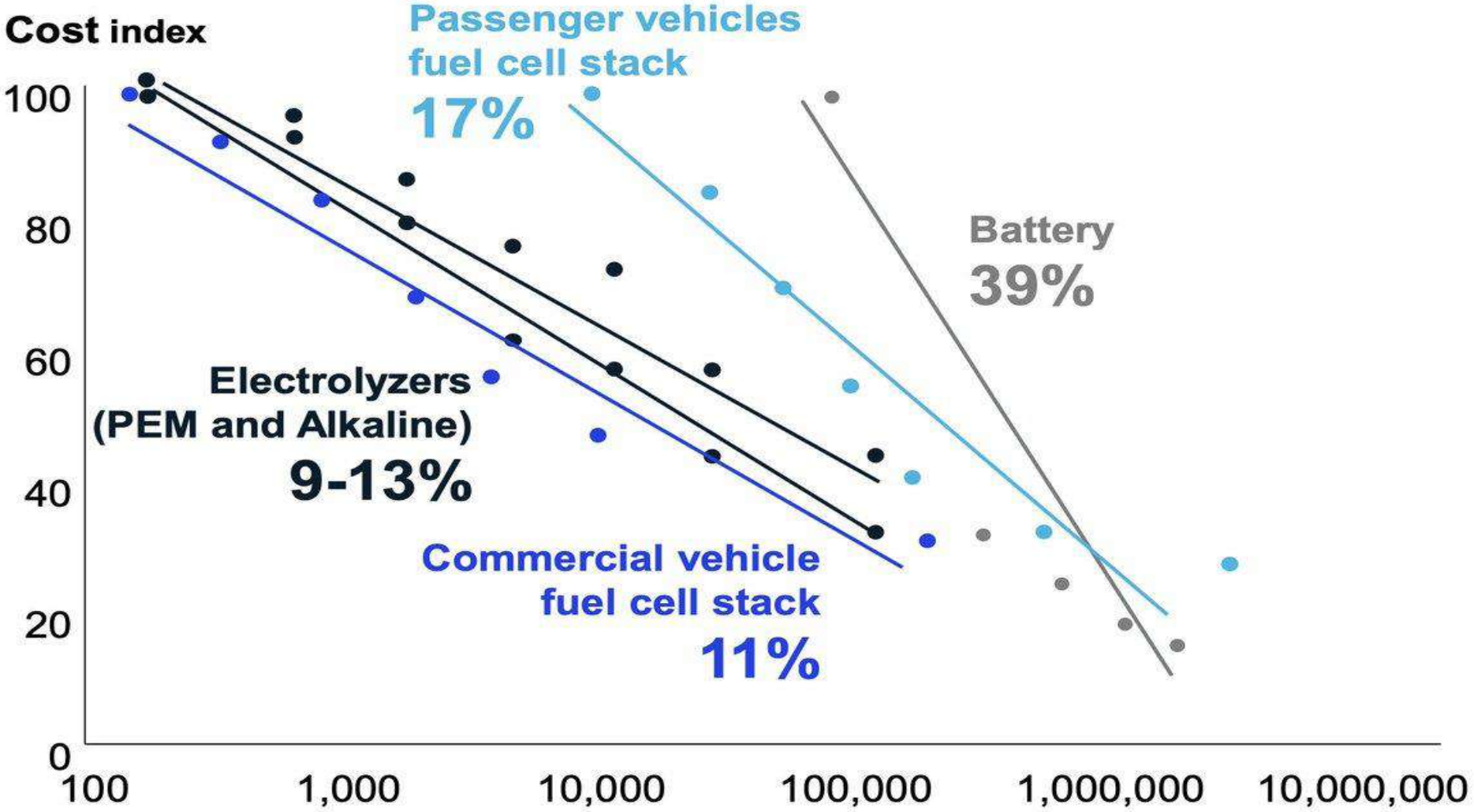
- Future characteristics (e.g. costs) not a function of time, but dependent on intervening actions (R&D & investments)
- Improvements through accumulation of experience (learning + knowledge appreciation)
- Interactive rather than linear model: Learning by doing and using (supply push + demand pull + limits)

Supply Technologies Cost Trends



Source: Grubler et al, 2012

Learning curves could drive down capex of fuel cell and electrolyzer systems

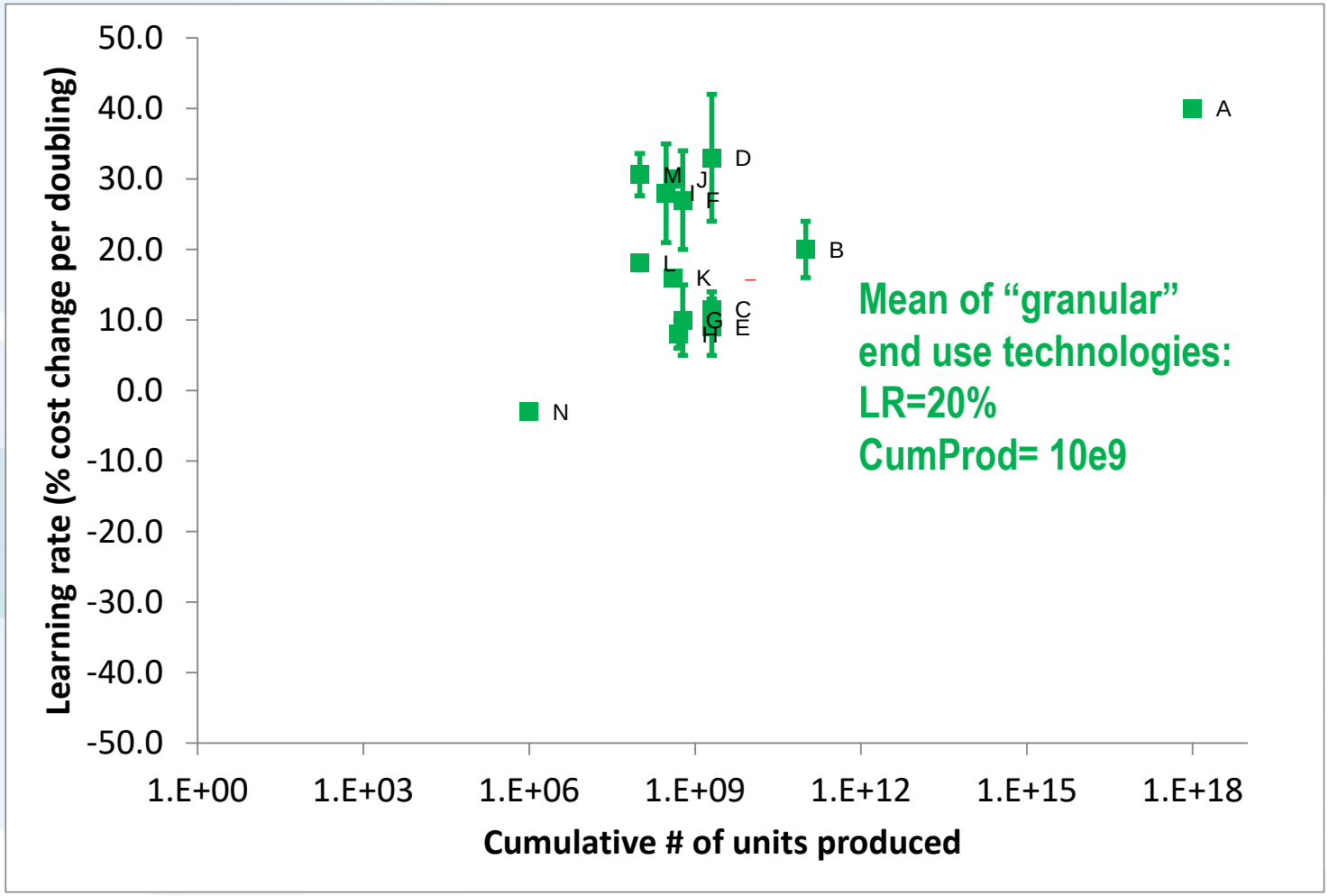


1. Battery 2010-20, fuel cell and electrolyzer 2020-30

Source: Hydrogen Council: Path to hydrogen competitiveness: A cost perspective

TWI2050 The World in 2050

Cumulative Experience and Learning
The Importance of "granularity"



A Transitors
B DRAMs
C Automobiles
D Washing machines
E Refrigerators
F Dishwashers
G Freezers (upright)
H Freezers (chest)
I Dryers
J Calculators
K CF light bulbs
L A/C & heat pumps
M Air furnaces
N Solar hot water heaters

Source: Wilson et al, Nature CC, 2012

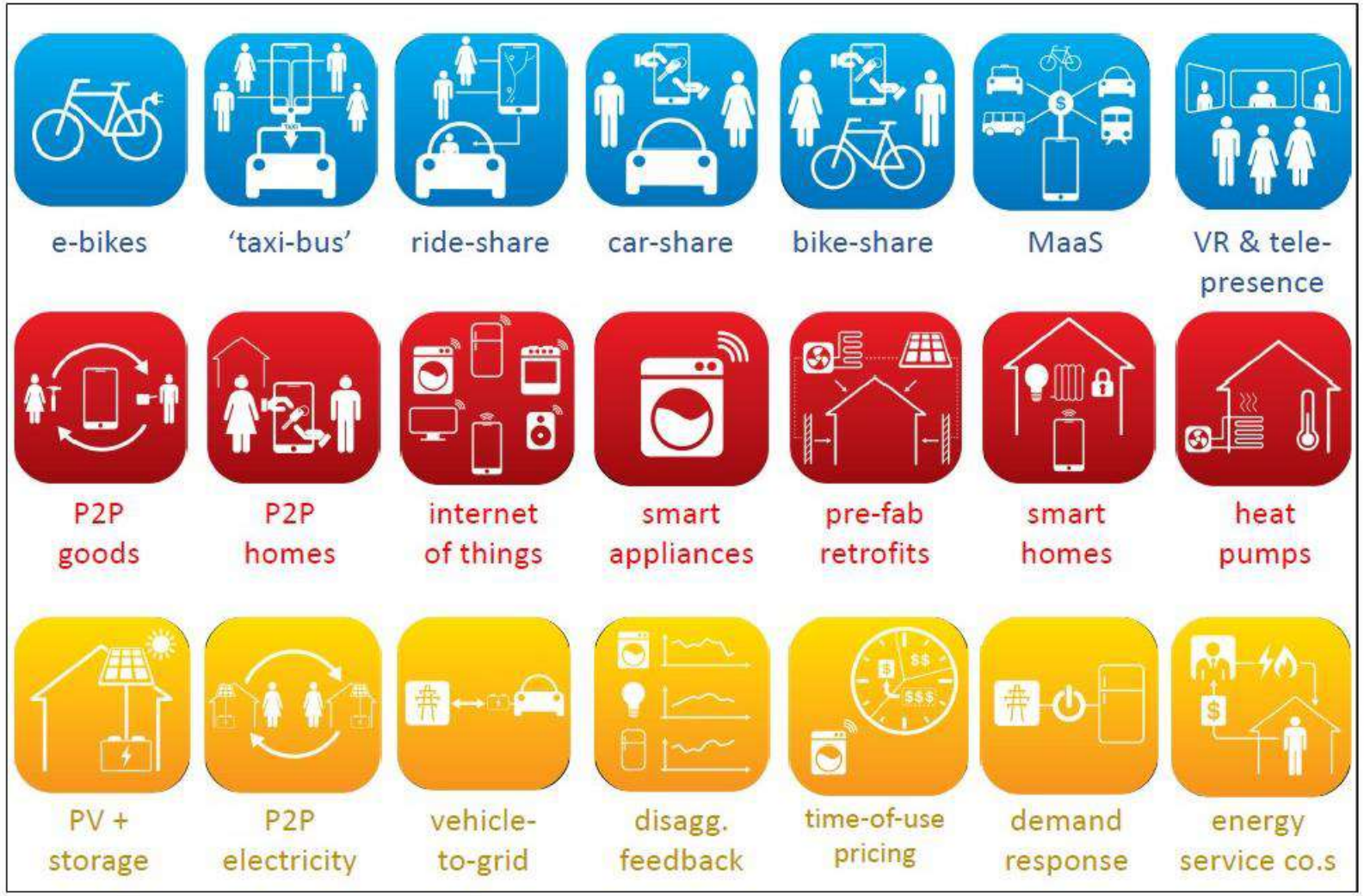
Hydricity Age – Proton and Electron
Synergies and Complementarity

Both

- H_2 and electricity can be produced from *any source*
- H_2 and electricity can be *interchangeably converted*
- H_2 and electricity are *renewable*

Source: David Sanborn Scott, 2004

Disruptive Digital Innovations



(1) From ownership to usership – (2) Sharing Economy – (3) From atomized to connected

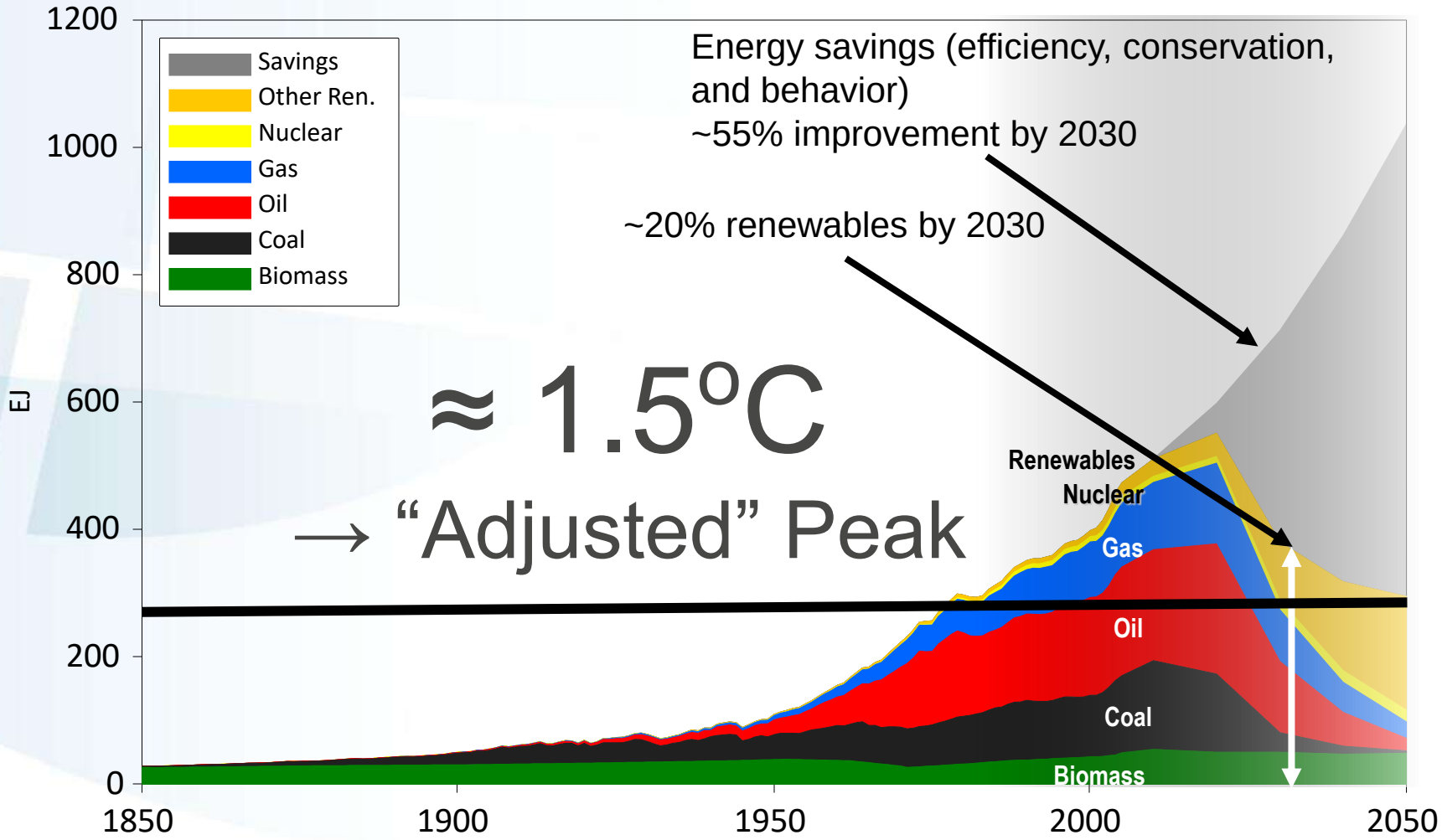
24h Le Mans 2023 – Future is Hydrogen


Finabel
European Army Interoperability Centre
Info Flash
Future Hives
Drone Swarms
Written by Flaminia Del Monte
Photo by www.thetimes.co.uk via Getty Images

Progress Eagle

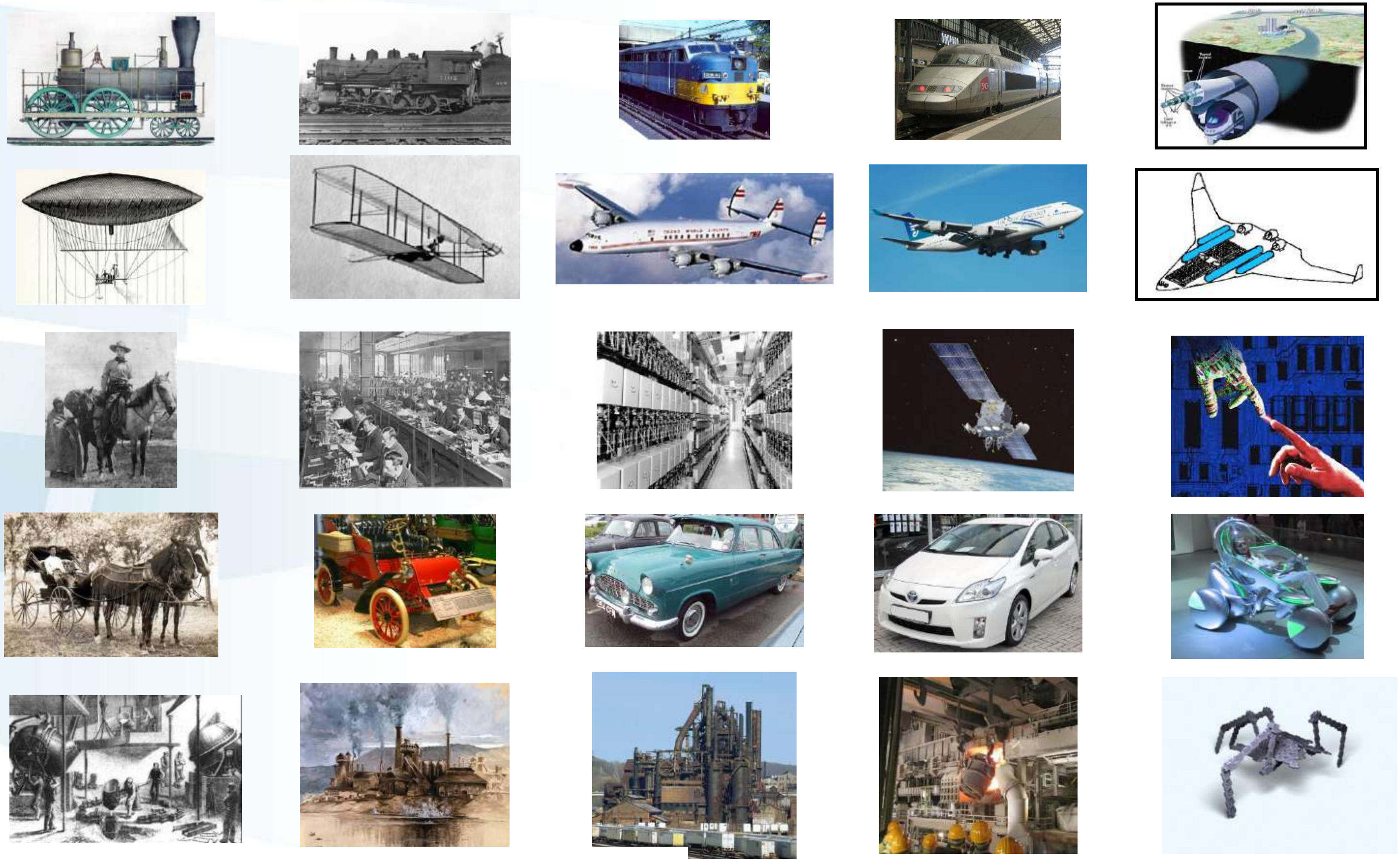
Global Primary Energy

ALPS Low Energy Demand (LED)



Transformational Change

1850 1900 1950 2000 2050



Source: After Granger Morgan, 2013

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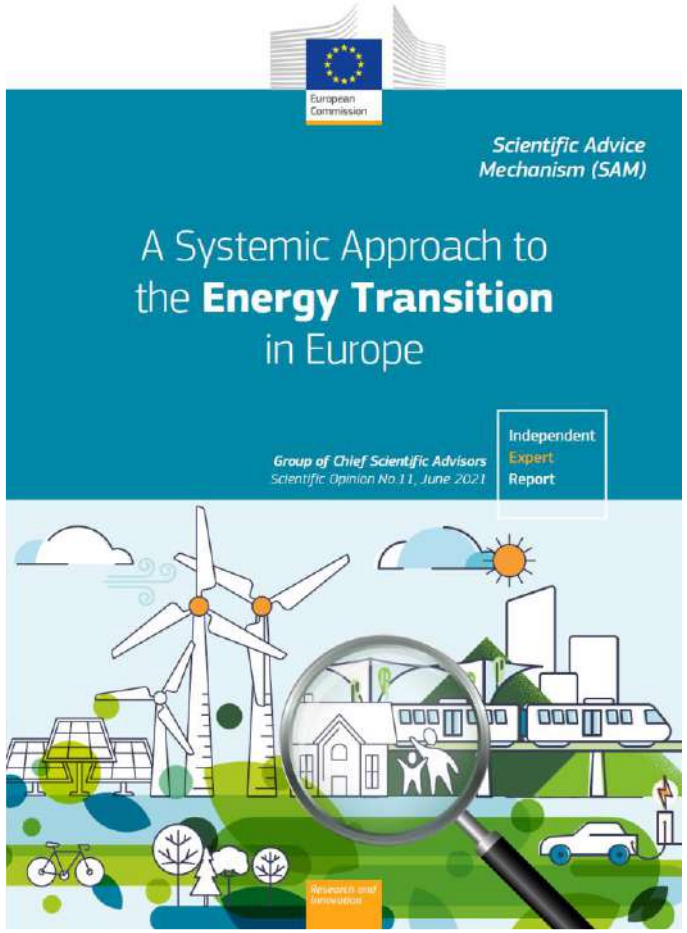
science for global insight

THANK YOU - HVALA



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