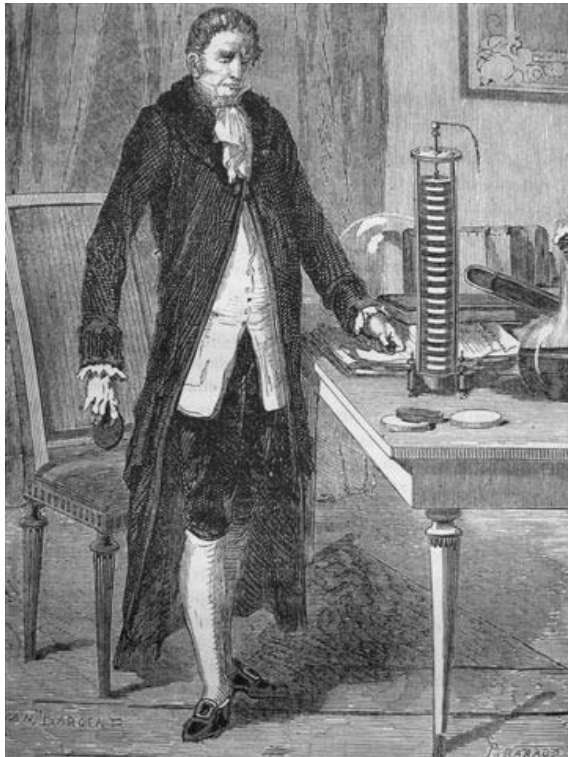


Brennstoffzellen – Energiewandler der Zukunft

Prof. Dr. Peter Strasser

1800: Volta'sche Säule - Erste fließende Elektrizität

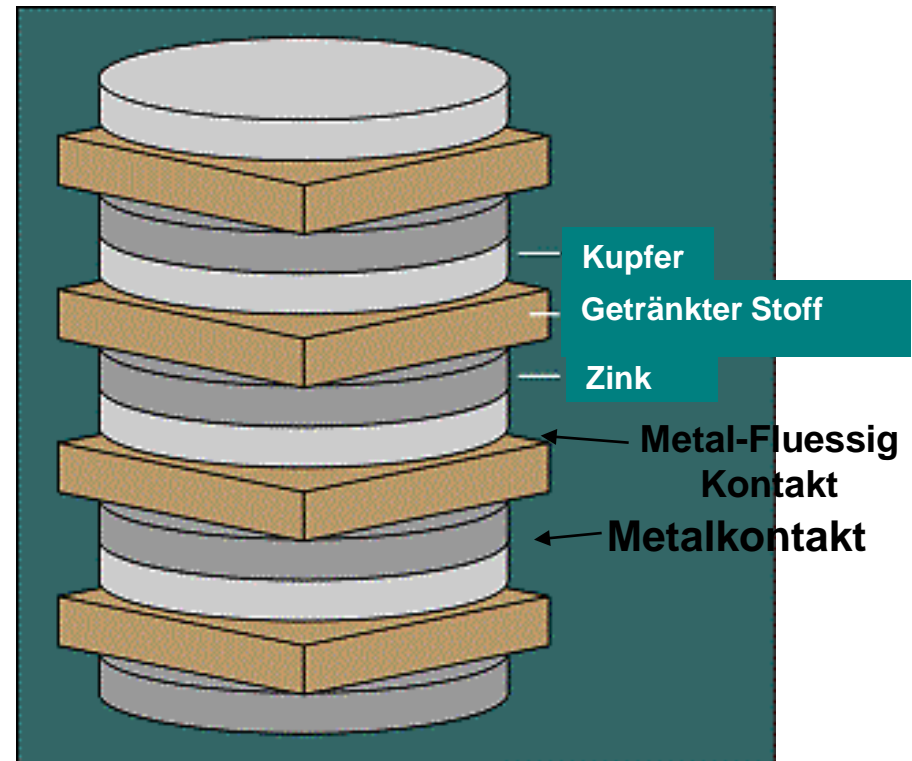
Alessandro Volta



"On the Electricity Excited by the Mere Contact of Conducting Substances of Different Kinds."

A. Volta, (1800)

Die Cu-Zn Voltasche Säule



"Metallic chemical energy → Electrical energy"

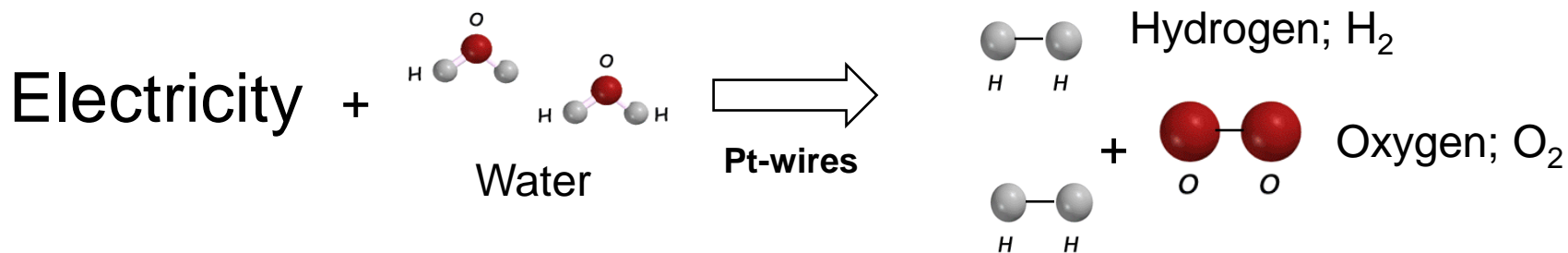
'French Nobel Prize'



Alessandro Volta presenting his 'Voltaic Pile' to Napoleon 1801

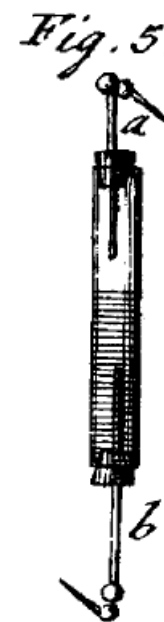
By Giuseppe Bertini

1801: Pt-catalyzed water splitting (“Electrolysis”) into H₂ and O₂

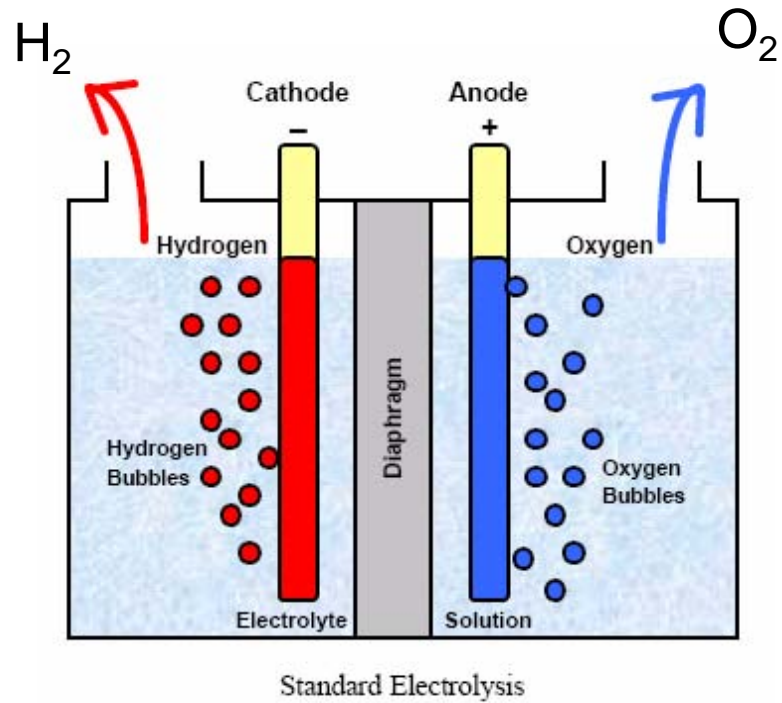


Electrical energy \rightarrow Chemical energy

Johann W. Ritter
(1776-1810)

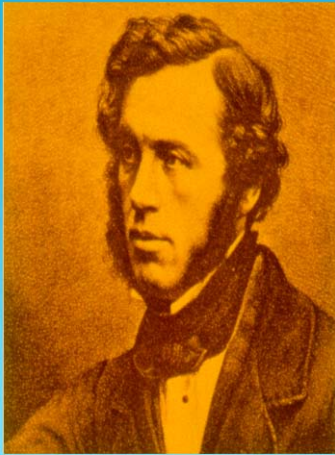


Moderne Wasser Elektrolyseure – niedriger Wirkungsgrad



50 % Wirkungsgrad

1839: Pt-catalyzed "Gas Battery" (Fuel Cell = Brennstoffzelle)

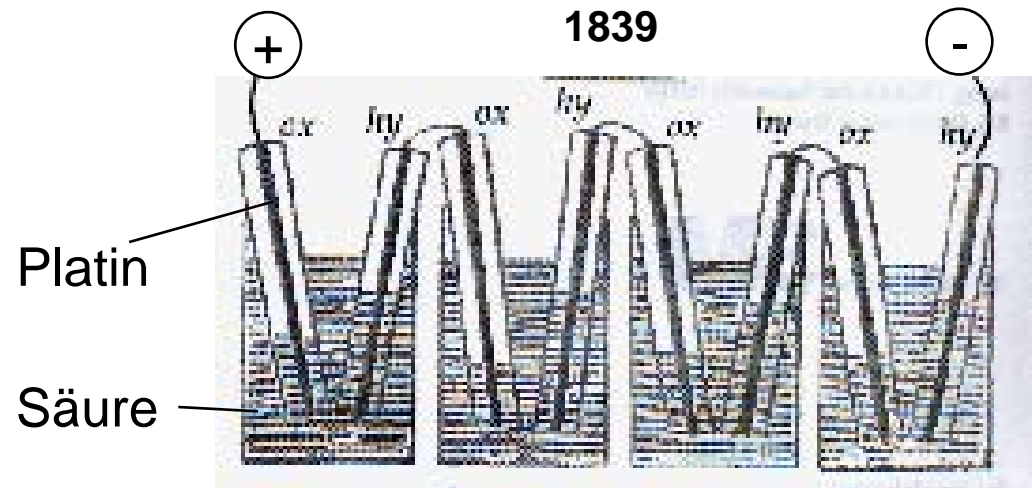


William Grove

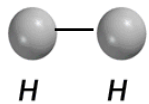


Sir William Grove
(1811 – 1896)

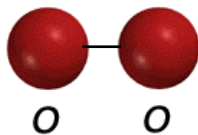
The "Grove" H₂ / O₂ Gas battery



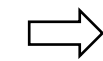
Hydrogen



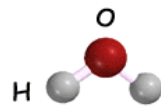
oxygen



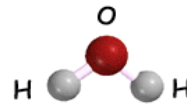
+



Pt-wires



Water



Chemical energy → Electrical energy

+ Electricity

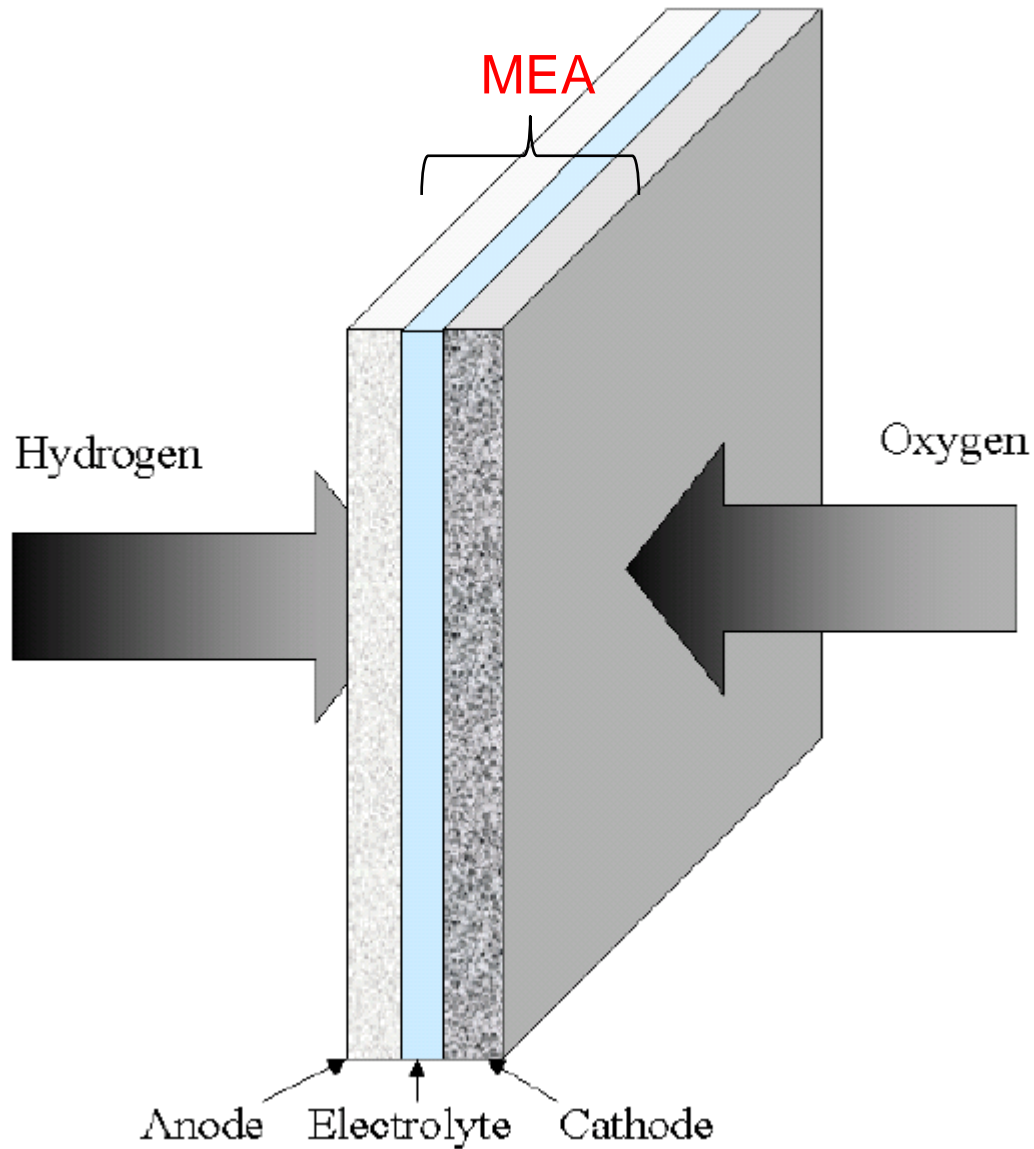
Was ist eine Brennstoffzelle ?

- **Elektrochemischer Energiewandler**

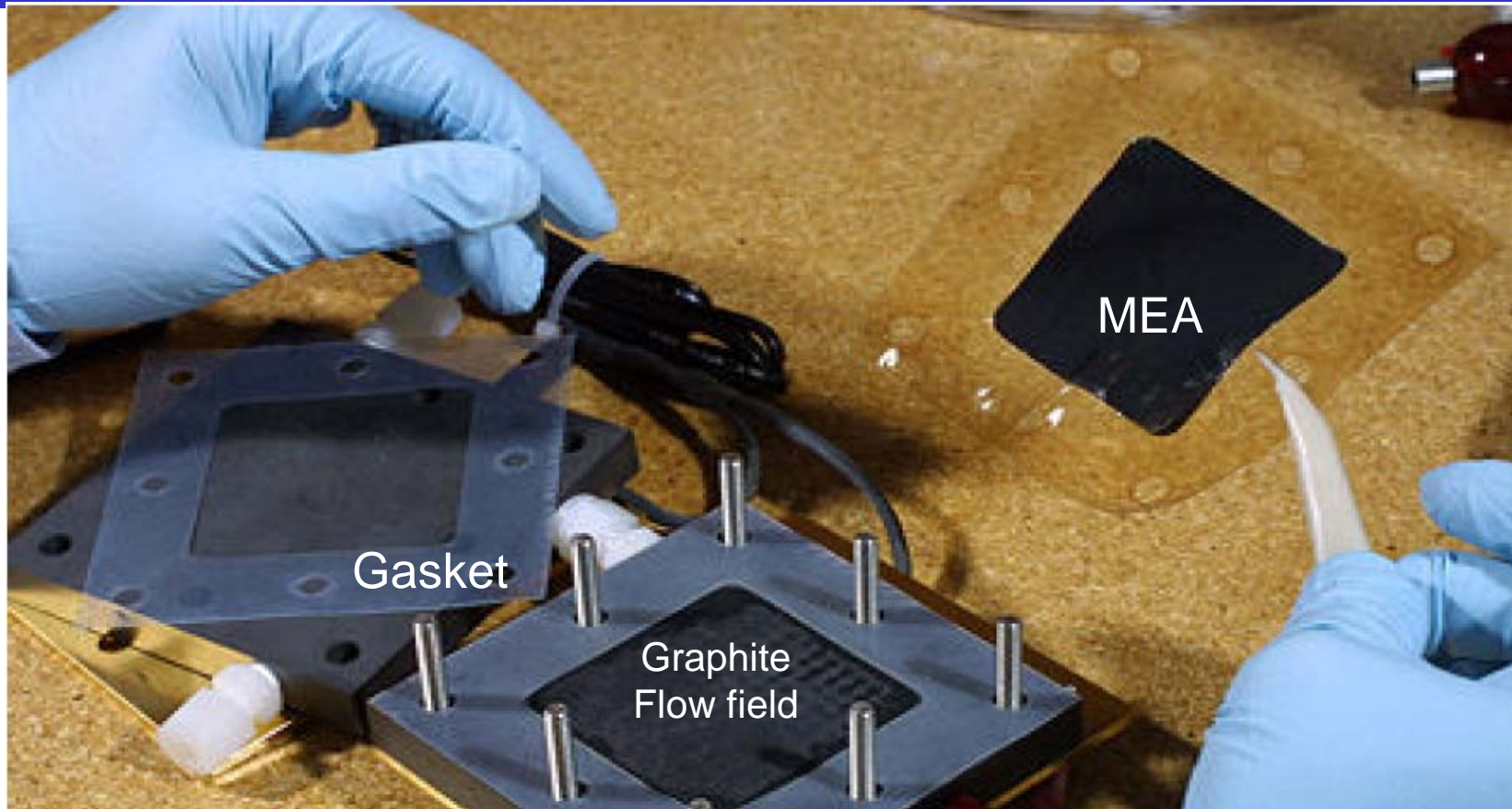
- ❖ Direkte Umwandlung von chemischer Energie in elektrische Energie
- ❖ Arbeitet wie eine “kontinuierliche Batterie”
- ❖ Speichert den Brennstoff ausserhalb der Zelle (←→ Batterie !)



Moderne Brennstoffzellen: Das Membrane-Electrode-Assembly (MEA)



Building a modern Fuel Cell : MEA



Membranes (MEAs) = 75% of unit cost

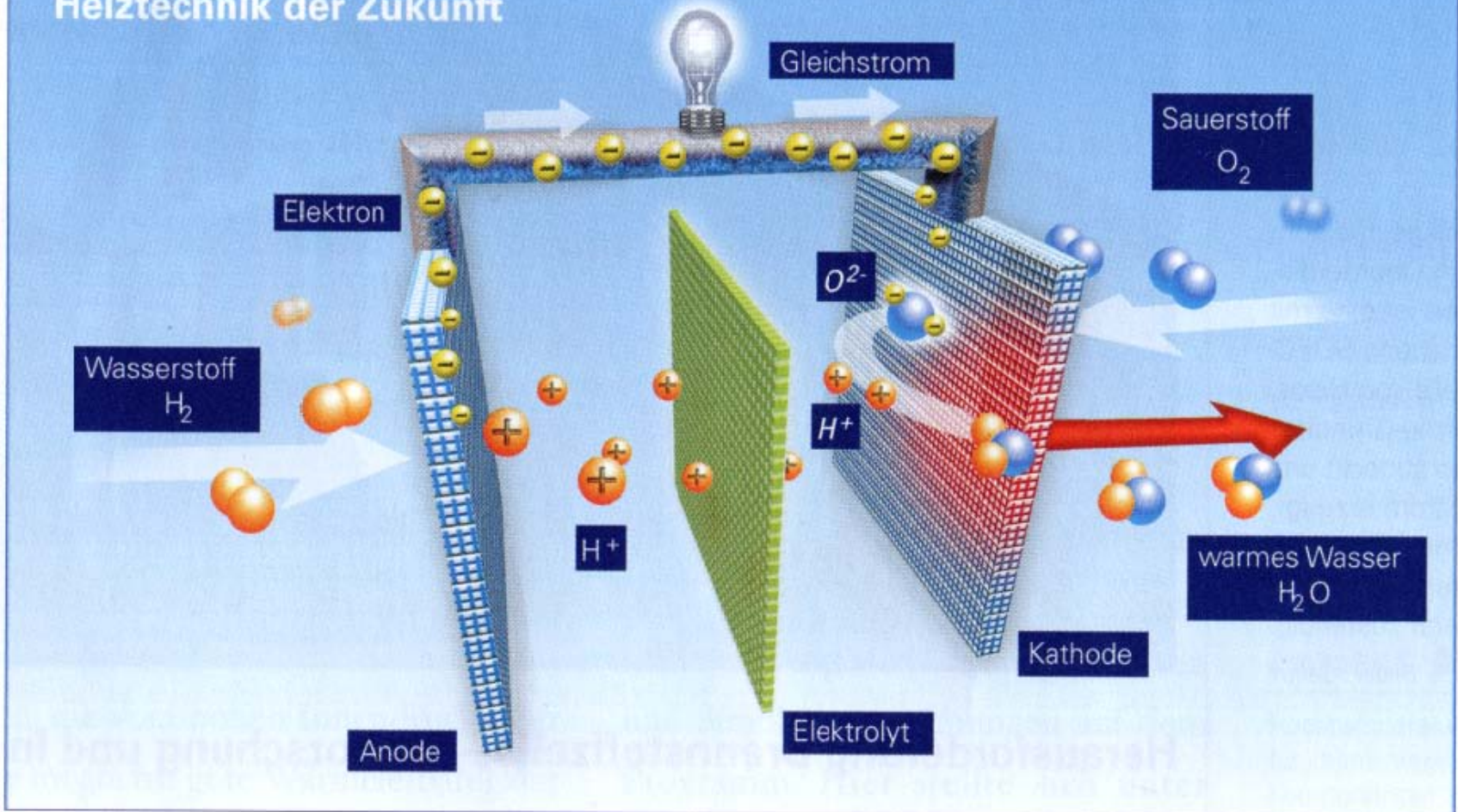


Cost reductions:

- Membranes/Catalysts
- Manufacturing

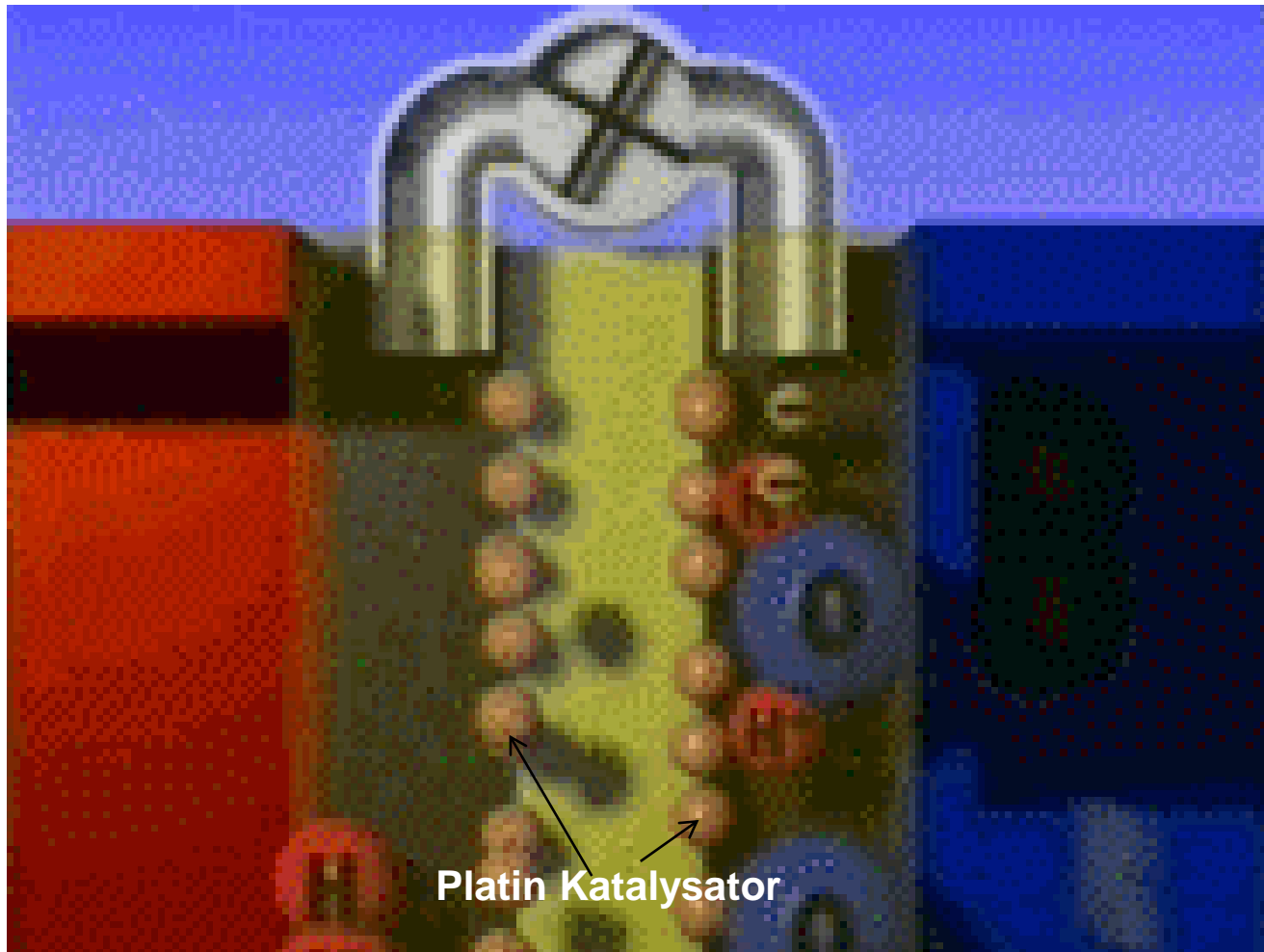
Die Brennstoffzelle

Heiztechnik der Zukunft



Strom und Wärme als Ergebnis der elektrochemischen Reaktion in einer Brennstoffzelle. Bild: Initiative Brennstoffzelle

Processes inside a Hydrogen Polymer Electrolyte Membrane Fuel Cell



Vorteile einer Brennstoffzelle

- **Wirkungsgrad** (50 – 80 %) höher als bei Benzin/Diesel Verbrennungsmotor (20 – 35%)
 - **Flexibilität des Brennstoffs**
 - ❖ **Wasserstoff** kann auf verschiedenen Wegen gemacht werden
 - ❖ **Alkohol**-Ethanol (aus Fossilem Brennstoff oder aus Biomasse)
 - ❖ **Methanol** (aus Fossilem Brennstoff , Biomasse, CO₂)
 - **Geräuschlos, vibrationsfrei**
 - **Brennstoff ausserhalb der Zelle gespeichert**
-

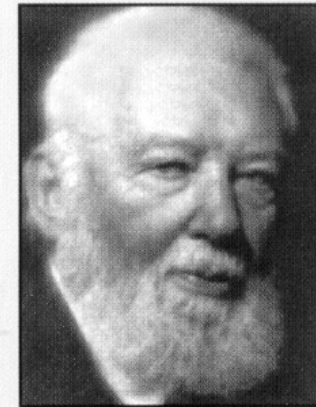
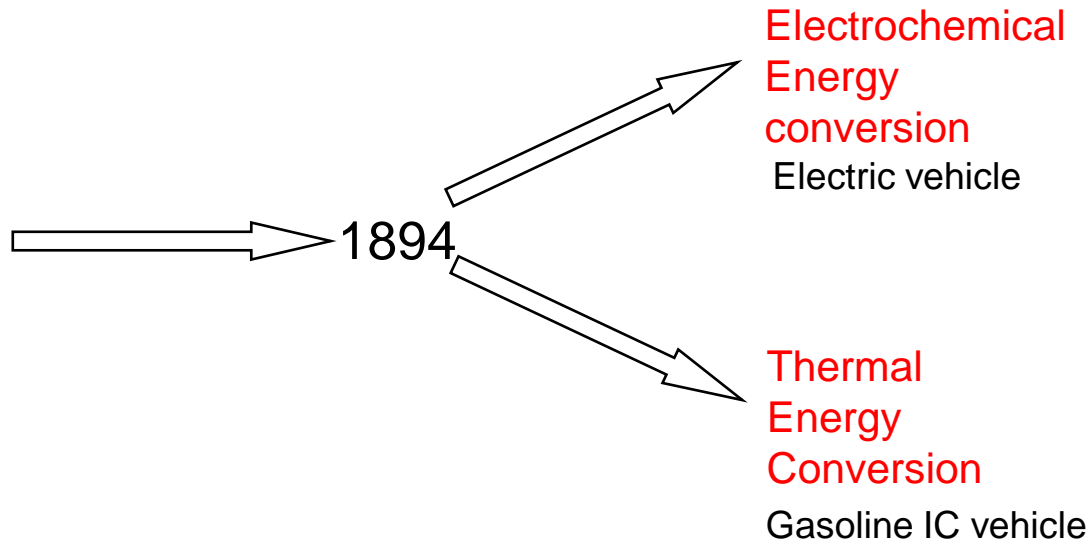
Brennstoffzelle \leftrightarrow Verbrennungsmotor/Generator

“Ich weiss nicht ob man sich vergegenwaertigt, was fuer ein unvollkommenes Ding die Dampfmaschine ist..Von der Energie der Kohle erhalten wir in gestalt von Arbeit im besten Falle 10%....

*Der Weg nun auf welchem die groesste aller Fragen, **die Beschaffung billiger Energie**, zu loesen ist, dieser Weg muss von der **Elektrochemie** gefunden werden....*

Die Brennstoffzelle ist eine Umwaelzung, gegen welche die Dampfmaschine verschwindet.

Aus: “Die wissenschaftliche Elektrochemie der Gegenwart und die technische der Zukunft”
Wilhelm Ostwald, 2. Jahrestagung Deutscher Electrotechniker, Leipzig, 1894



Wilhelm Ostwald, 1853–1932

**Warum brauchen wir
Brennstoffzellen ?**



13,000,000,000,000 thermal Watts = 13 Terawatts

Primary Energy Carrier and their use – no alternative to oil for mobility

**Transportation /
Mobility**

**Stationary electrical power
(Home, Industrial)**

Too valuable
to burn

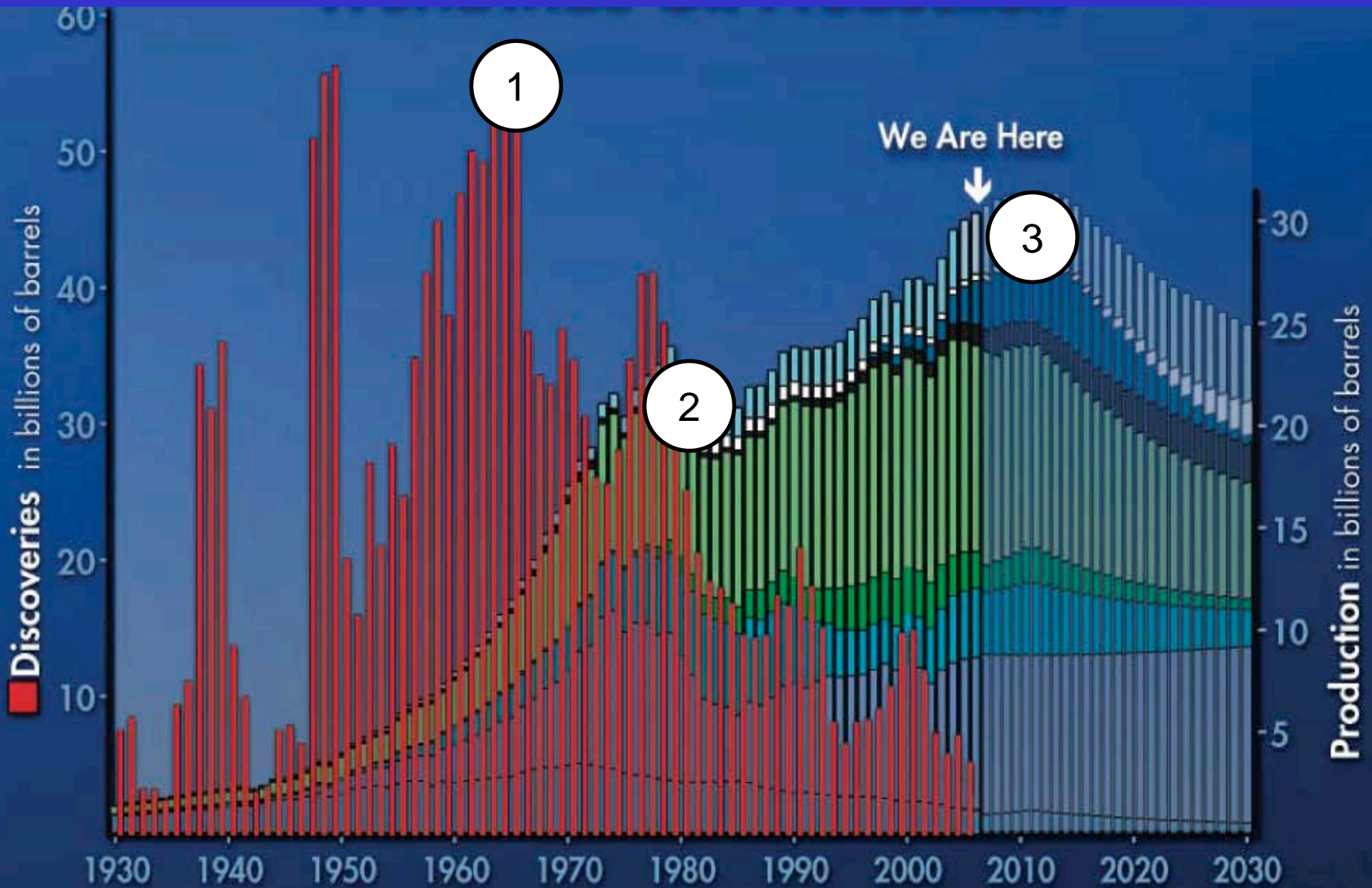
Household

Chemical Industry
Plastic, Pigments,
Intermediates
Pharmaceuticals

Beaumont Texas - Spindletop "Gusher", 1901 – cheap oil !

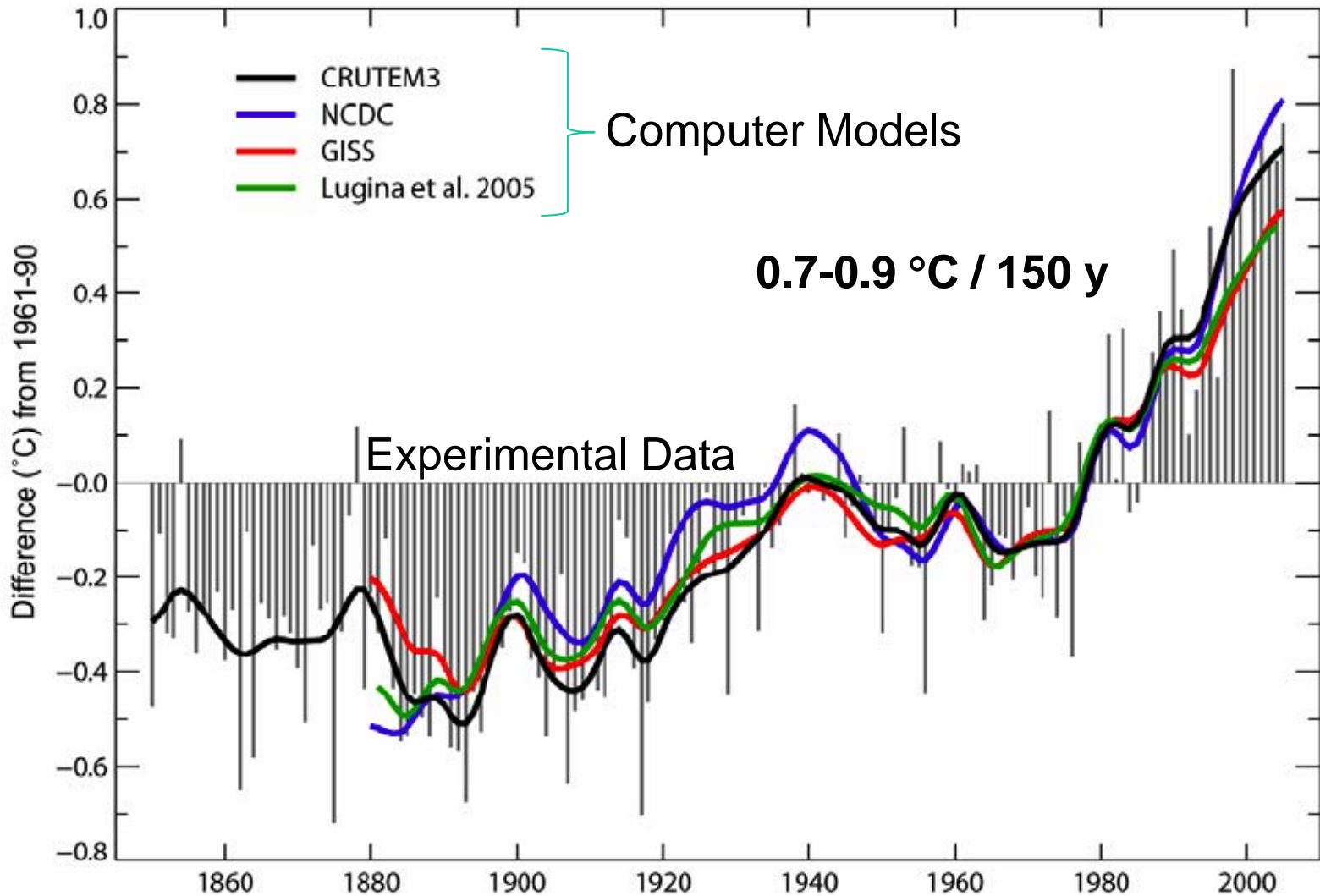


World Oil discovery and production – 3 x “Peak oil”



Source: ASPO-USA; created by OilPoster.org, Energy Watch Group 2008 ; www.energywatchgroup.org/

Average Surface Temperature

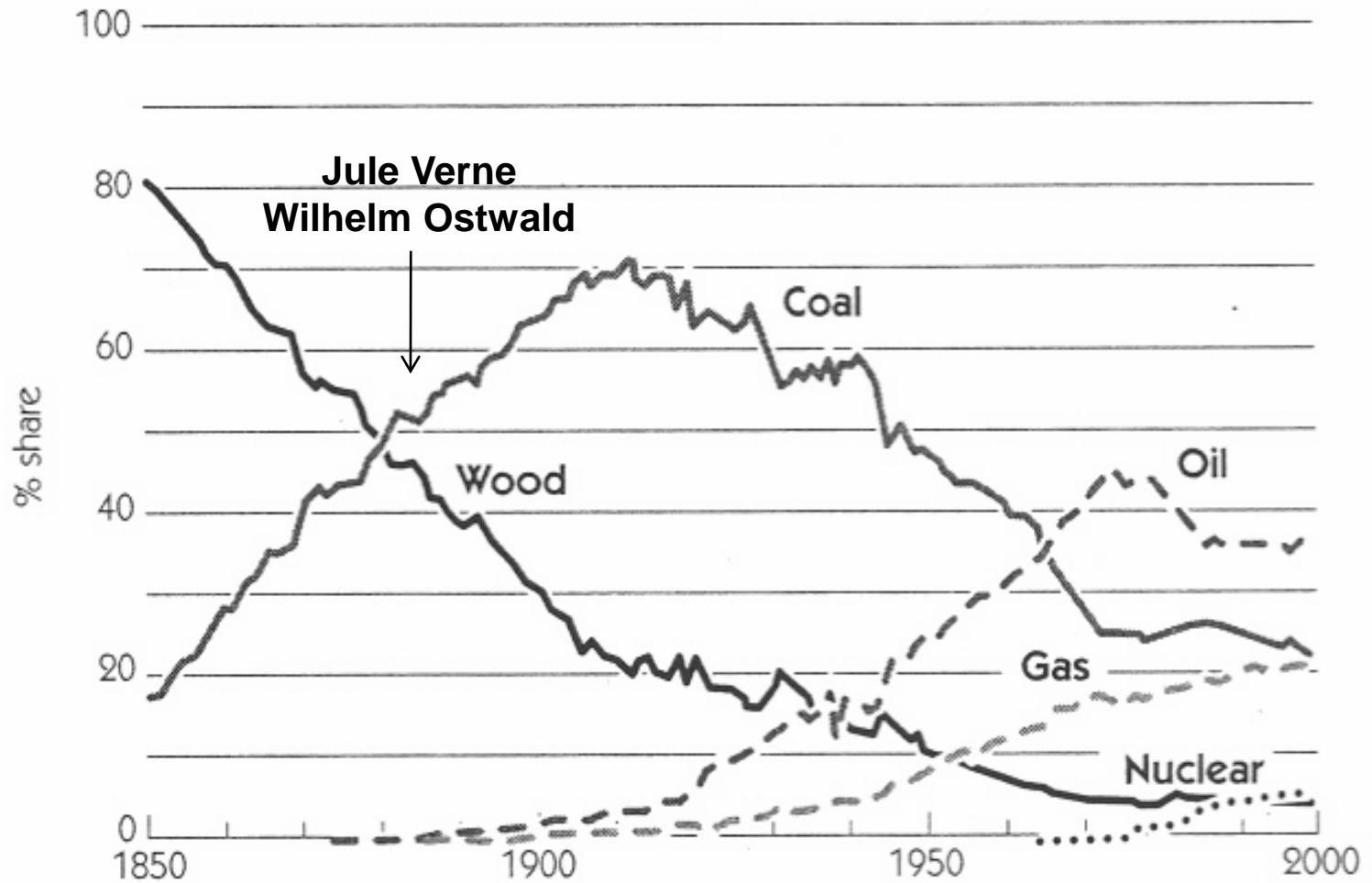


Warum Brennstoffzelle ?

- Minderung unserer Abhängigkeit von Rohöl durch Flexibilisierung unserer Brennstoffe und Primaerenergien
 - Klimaverträgliche Energieerzeugung
 - Technologieführerschaft und wirtschaftliche Vorteile
-

**Welche Brennstoffe kommen in
Frage ?**

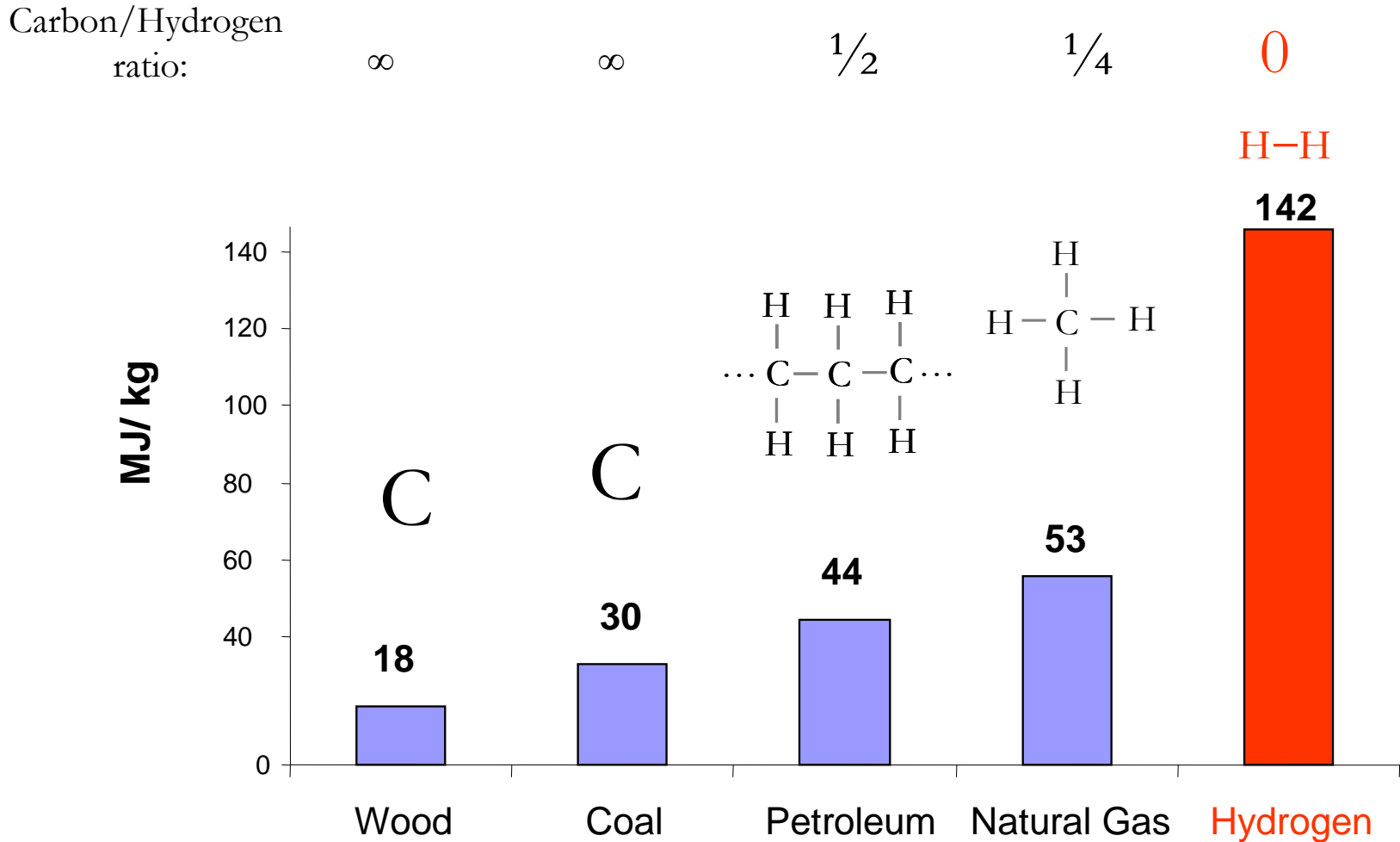
Historic Primary Energy Substitution - Decarbonization



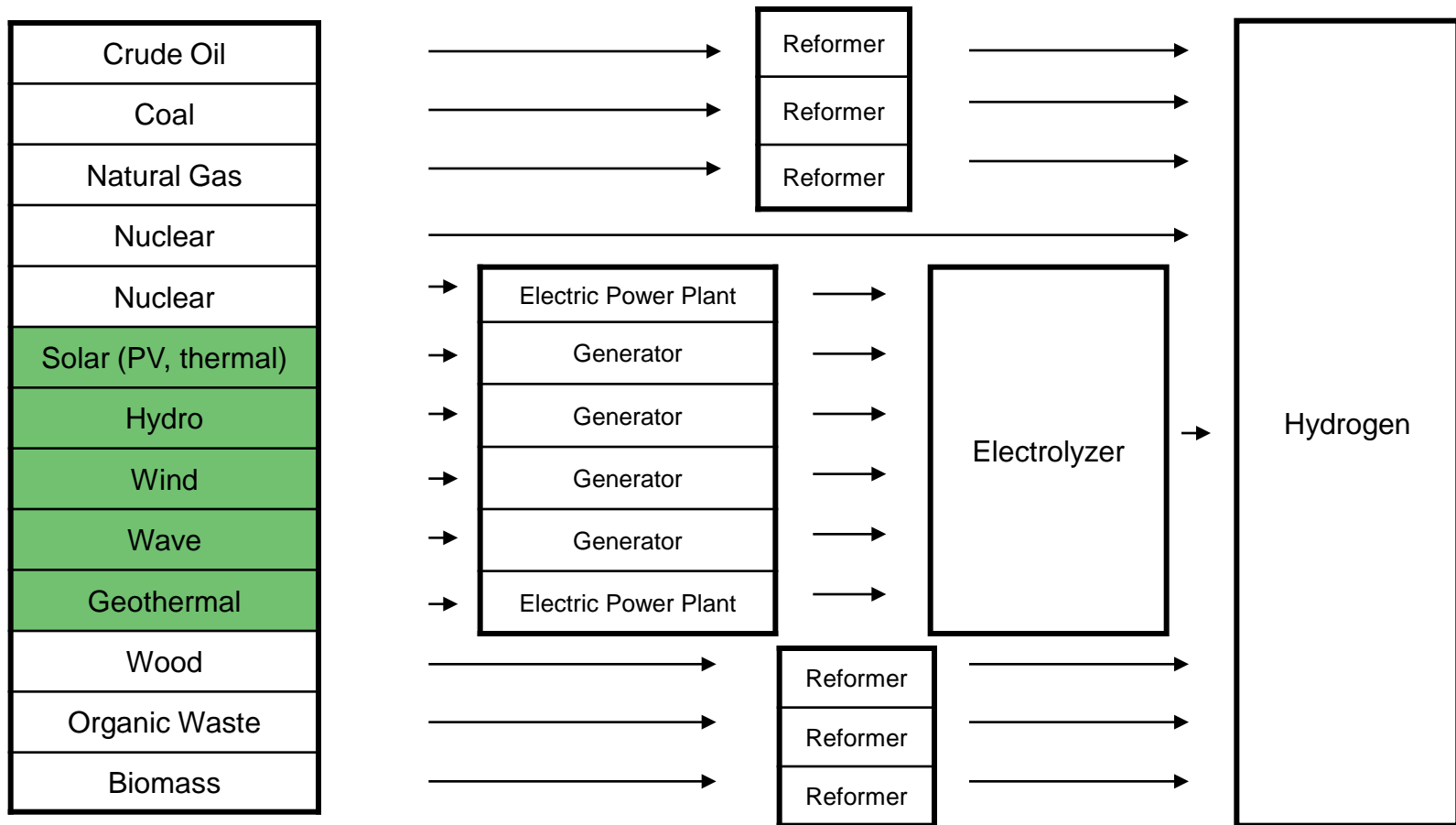
Source: Dr. Nebojsa Nakicenovic, International Institute for Applied Systems Analysis, Laxenburg, Austria.
Private communication, Aug. 20, 2003.

The global decarbonization of fuels

- Carbon/Hydrogen ratio approaching zero during human history
- Hydrogen offers high energy density

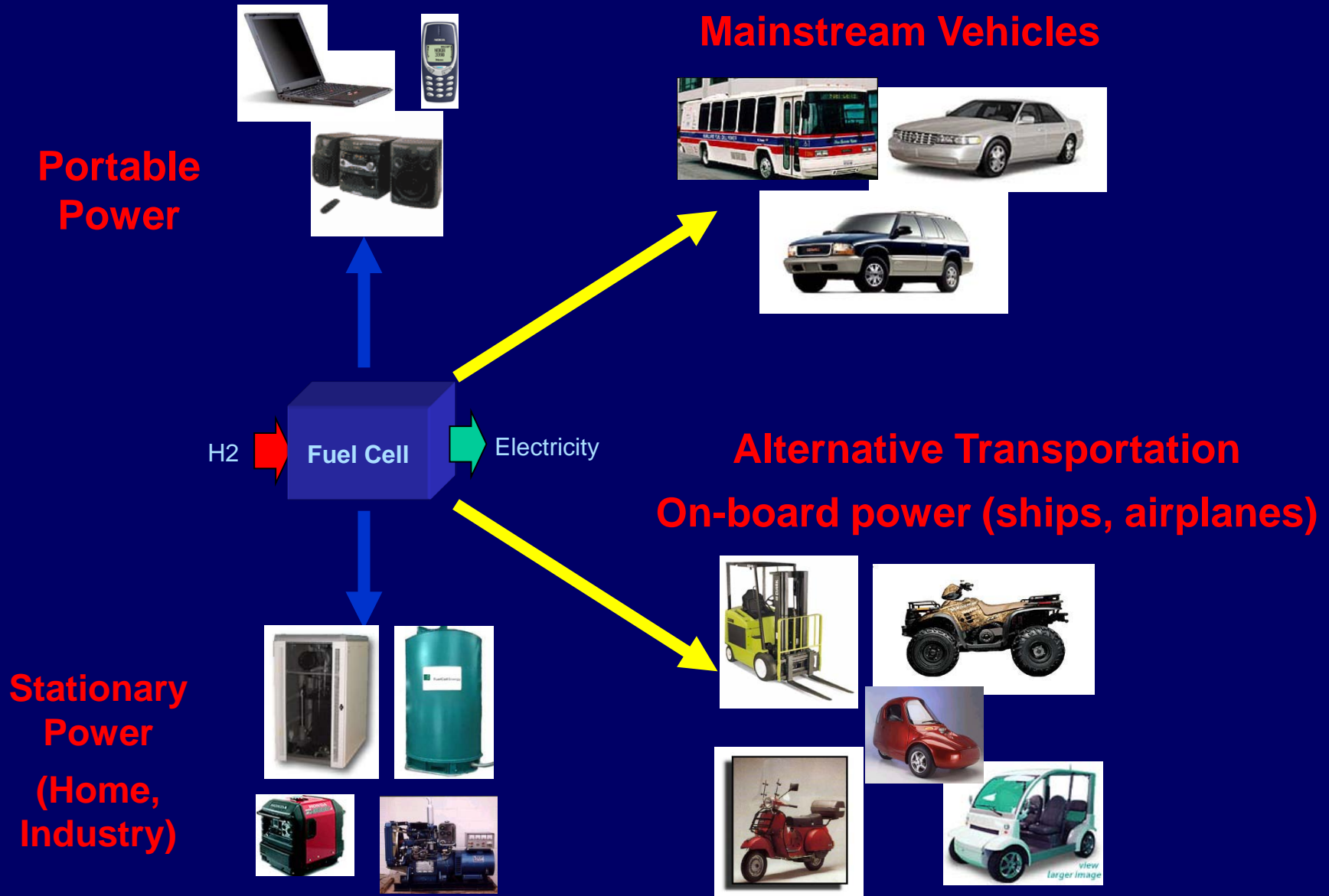


Flexibility of Hydrogen Fuel Pathways – Hydrogen is energy carrier!

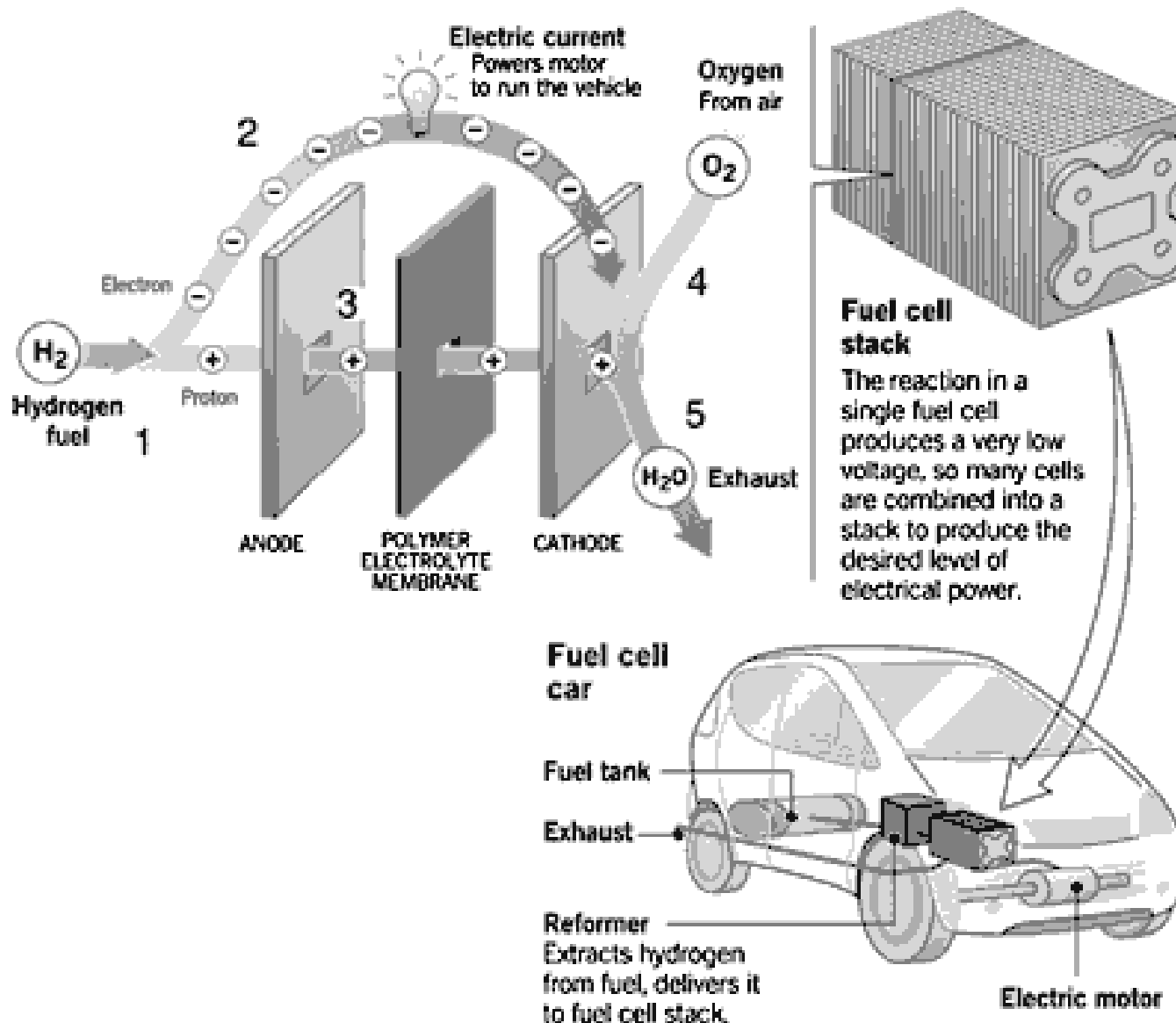


Anwendungen der Brennstoffzelle

Fuel Cell Power Markets



Brennstoffzellen Stack + Elektromotor = Antrieb



Hydrogen-fueled zero-emission vehicles



**Clockwise from top left:
Hyundai, Daimler-Chrysler,
Ford, Nissan, Volkswagen,
Honda, GM(center)**



Honda FCX Clarity: The future is fuel-cell

Last Updated: 12:01am BST 20/06/2008

Honda has started production of the FCX Clarity fuel-cell car that goes on lease in California this year.

Honda has been flooded with requests for the new car and has had to draw lots even though leasers will be paying \$600 (£300) a

month, plus about \$4.1 (the FCX equivalent fuel consumption mpg). Actresses Jamie Laura Harris will be am

The striking four-door Motoring last year (Nov 2007). It is fuelled with hydrogen stored in a s produces electricity fo

The range is quoted at Honda's Ben Knight say par with a battery car build up to 300 FCX Cl



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FCX CLARITY

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 - Evolution
 - Hydrogen Safety
- How FCX Clarity Works
 - V Flow
 - Battery
 - Motor
 - Powertrain
- Drive FCX Clarity
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- Press
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Drive FCX Clarity



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Forward

The FCX Clarity is ready for the road. A limited number of these groundbreaking vehicles will be leased to Southern Californians starting this summer.* Honda plans to deliver about 150 FCX Clarity hydrogen-powered fuel cell vehicles to customers in the first three years of its fuel cell lease program. The customer pre-qualification and selection process is already underway. The first FCX Clarity drivers will be announced at a special ceremony marking the start of production on June 16, 2008.

The Details

3-year \$600/month lease*

Leasing will be handled through American Honda Motor Co., Inc. in conjunction with local dealers.

Service & Maintenance Included



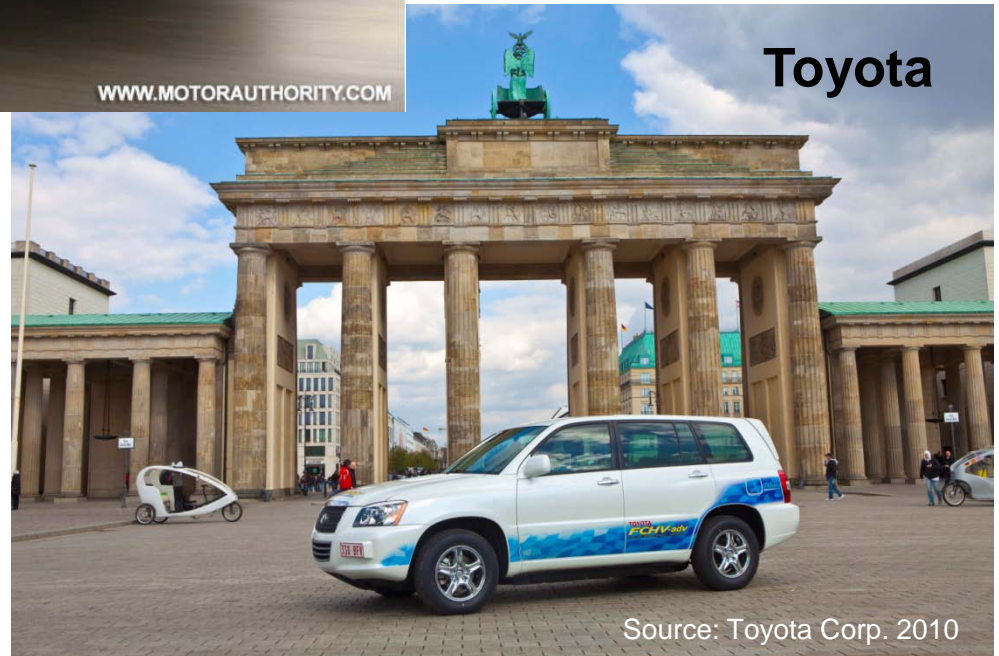
GM/OPEL



WWW.MOTORAUTHORITY.COM

Beide Wagen koennen
draussen
Probegefahren werden !

Toyota



Source: Toyota Corp. 2010

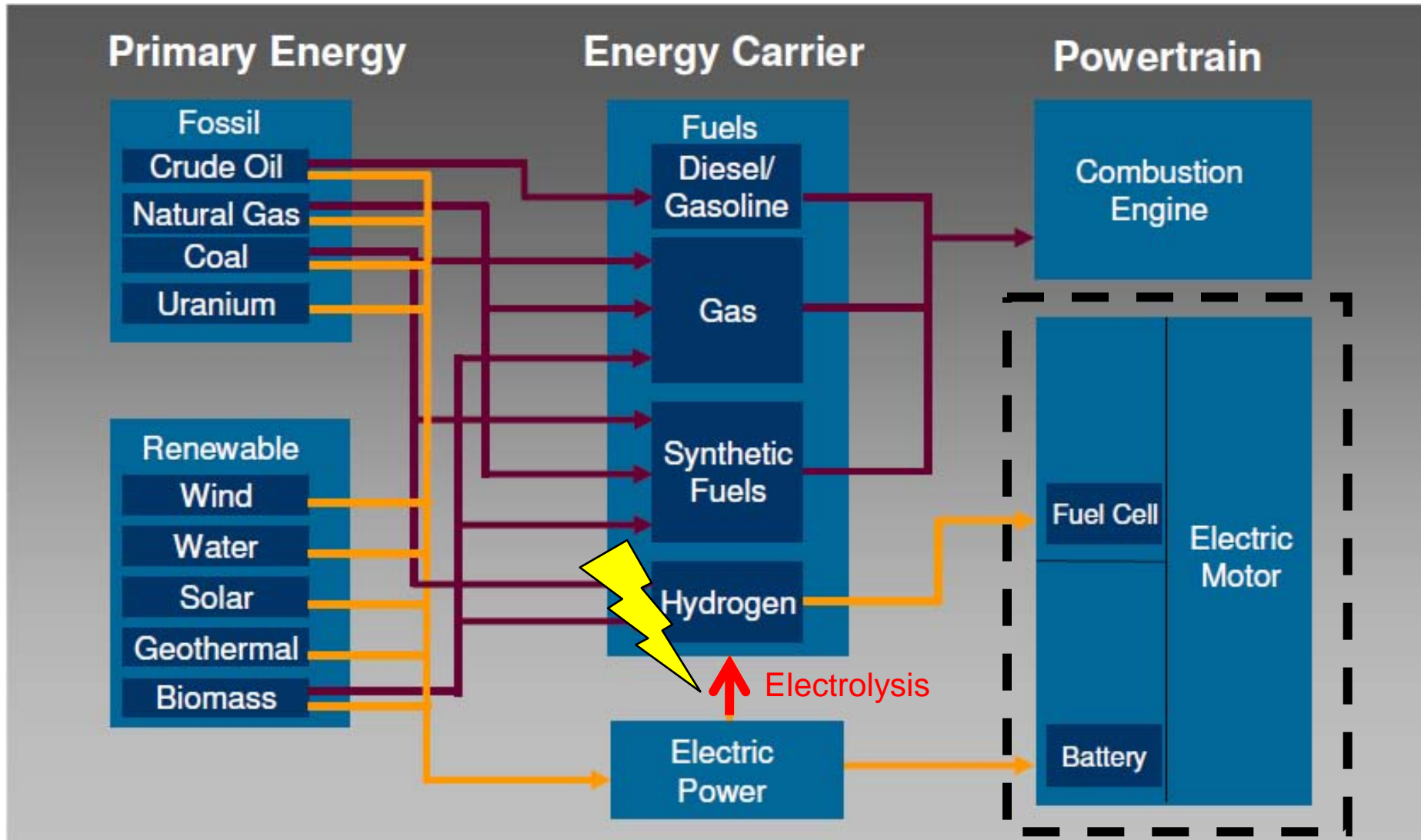
The HyFLEET:CUTE project



Batterie oder Brennstoffzelle ?

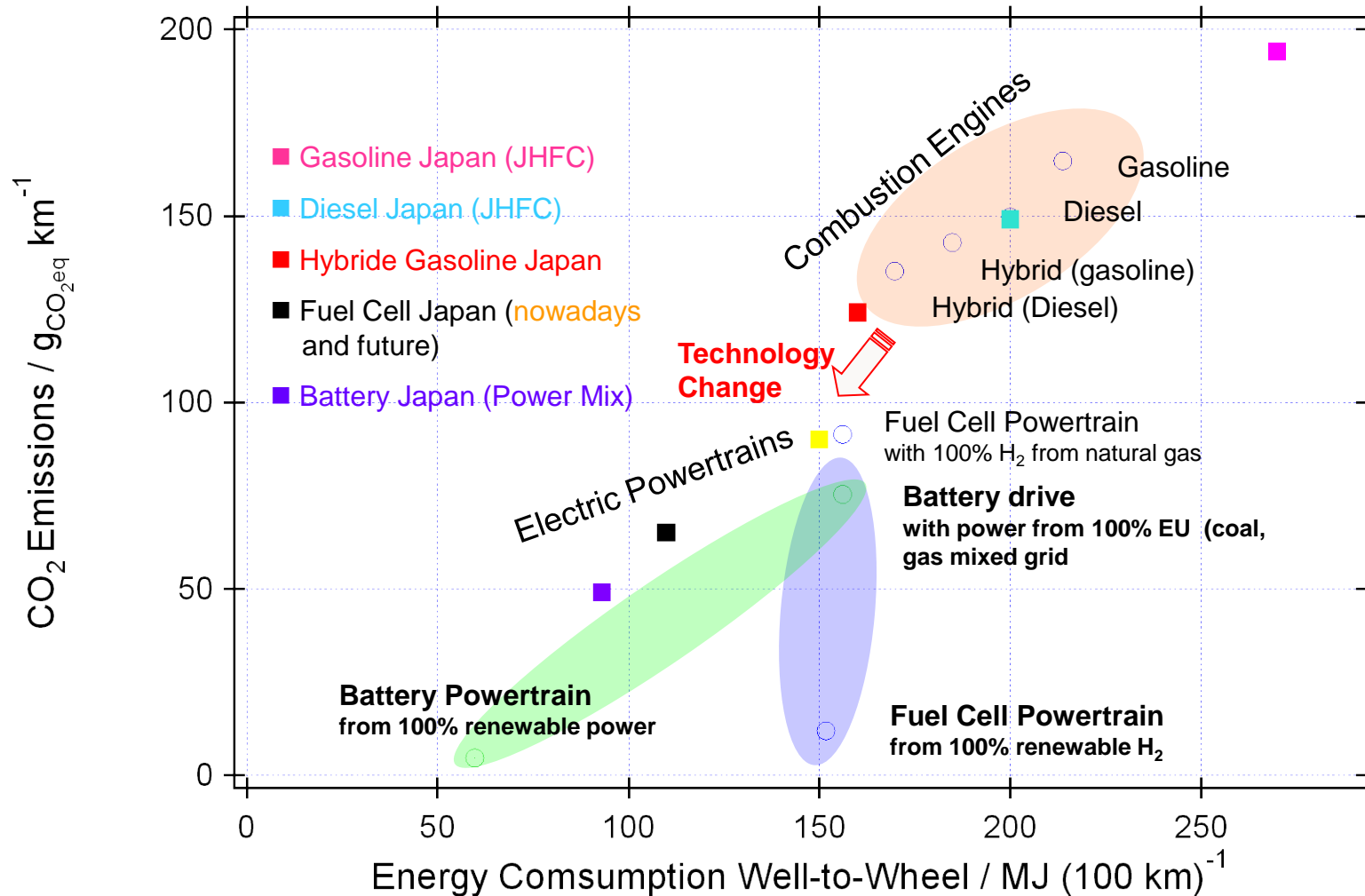


Fuel Choices and Automotive Power trains – Electrolysis is hurdle



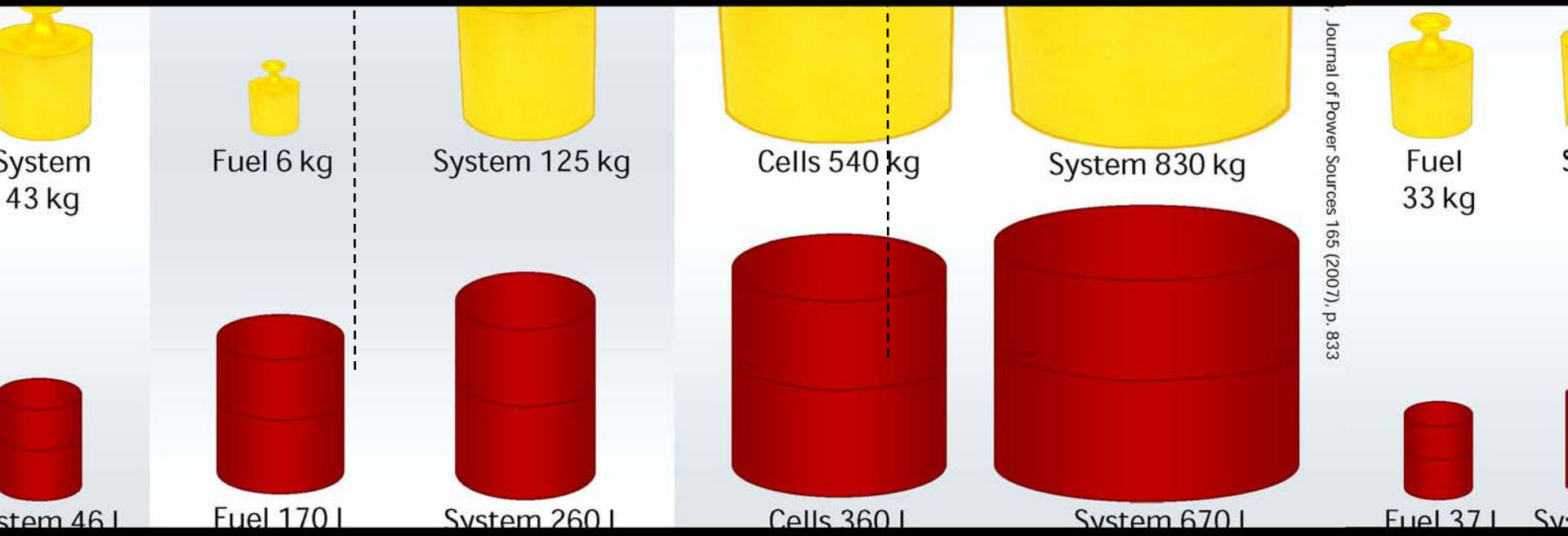
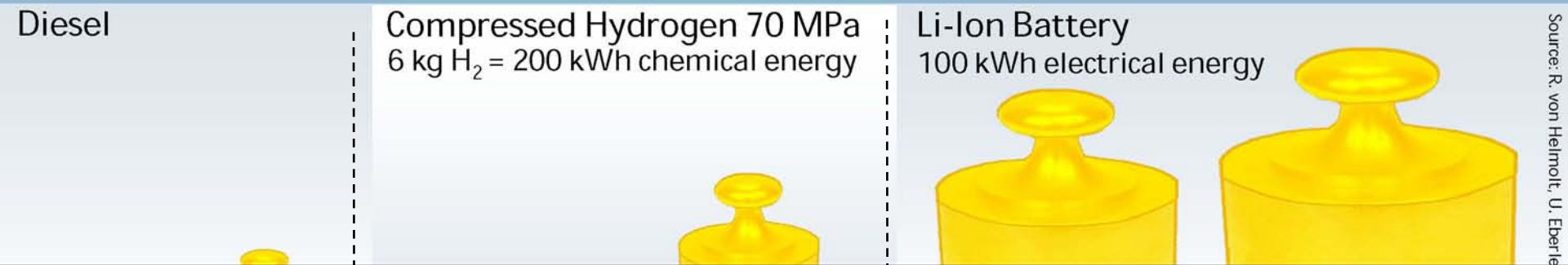
Wirkungsgradvergleich der Antriebe

➤ Elektrischer Strom fuer Batterieautos MUSS
aus erneuerbaren Quellen kommen – sonst kein Vorteil zu BZ



Weight and Volume of Various Energy Storage Systems

500 km Range



Journal of Power Sources 165 (2007), p. 833

Source: R. von Helmlolt, U. Eberle

Refueling fuel cells at sub-zero temperatures ok !



GM cold climate test in Canada

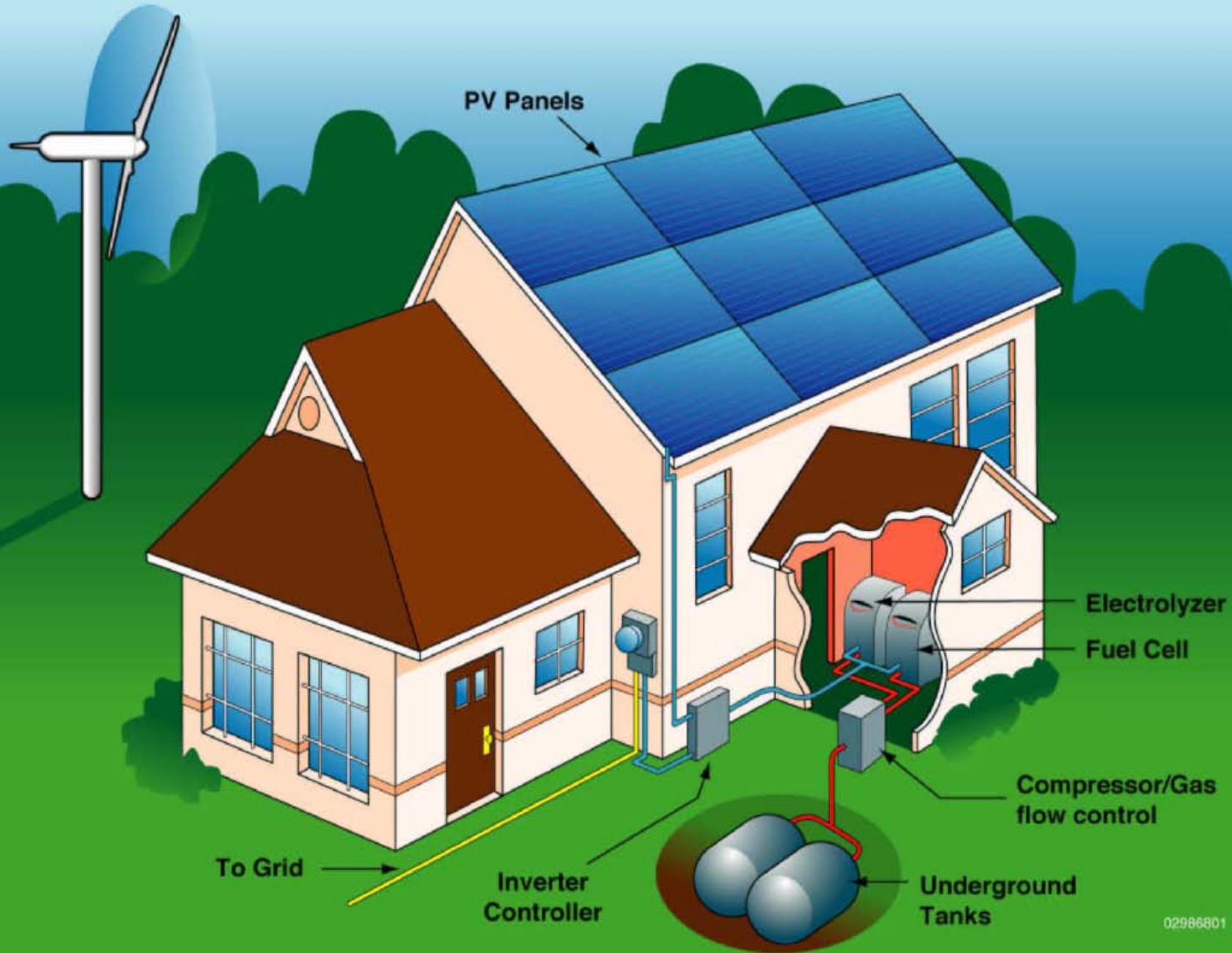
Vorteile und Nachteile des Brennstoffzellenantriebs

Vorteile

- Sehr kleine Wiederaufladezeit (3-5 min) \leftrightarrow 5-10 Stunden
- Kaltstart ($< 0\text{ C}$) \leftrightarrow Vorsicht bei Li -ionen Batterien
- Grosse Reichweite von 500 km mit 6 kg H_2

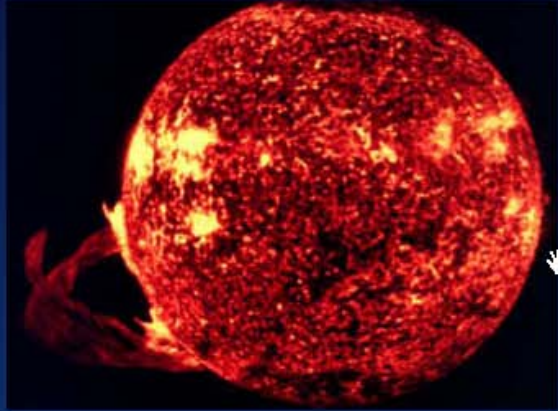
Nachteile

- Kleinerer Gesamtwirkungsgrad aufgrund Elektrolyse
 - Einbindung in Stromnetz unklar
-

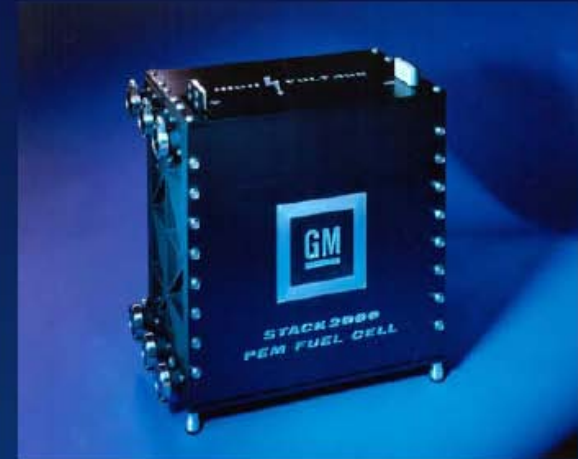
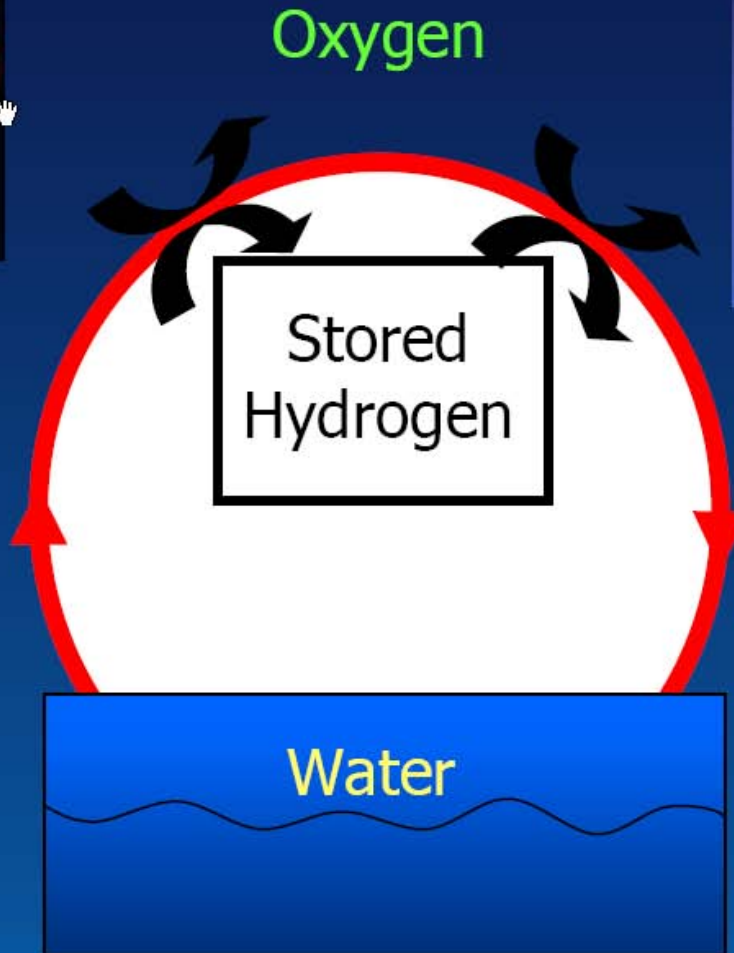


Die Wasserstoff Ökonomie

Closed Energy Cycle



Inputs:
Solar Energy and
Water



Fuel cell
Outputs:
Electricity, Heat
and Water

The End

EIN GROSSES DANKESCHOEN AN:

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Annegret Boegel

Jens Meissner

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Stefan Rudi

Frederic Hasche

Mehtap Oezaslan

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Dr. Launert, VW

