Solar Power From Space – SPS'04

Granada/Spain, 30th June – 2nd July 2004

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HYDROGEN PRODUCTION FROM SOLAR POWER SATELLITES

— THE HYDROGEN OPTION —

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Munich/Germany

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LBST – Company profile

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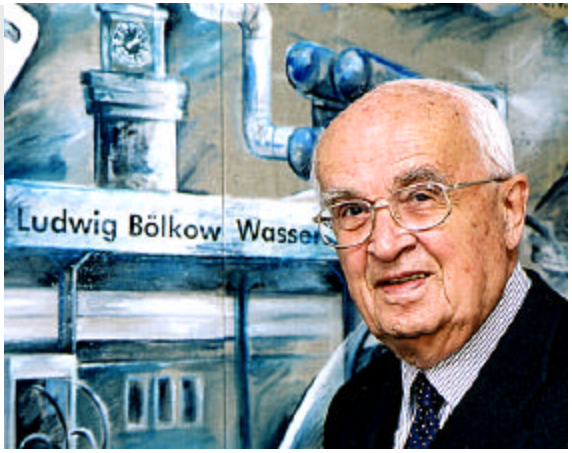
Strategy and technology consulting for sustainable energy and transportation systems



Dr. Ludwig Bölkow († 2003)

- Found in 1982 by Dr. Ludwig Bölkow
- Staff of 15 physicists, engineers, economists, assistants
- System concept approach
- Techno-economic perspective
- Fields of research: renewable energies, hydrogen and fuel cells, resource potentials
- Independent
- Worldwide customers base (industry, public bodies, NGOs, research institutes)

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Key drivers for hydrogen as transportation fuel

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- **Energy security**
- **Fossil resource constraints**
- **Environment**
- **Technology/product innovations**

Main fields of application of hydrogen/fuel cells

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- **Traction and on-board power supply**
  - Vehicles
  - Planes
  - Ships

Opel

- **Stationary generation of power and heat**
  - Residential
  - Commercial / Industry

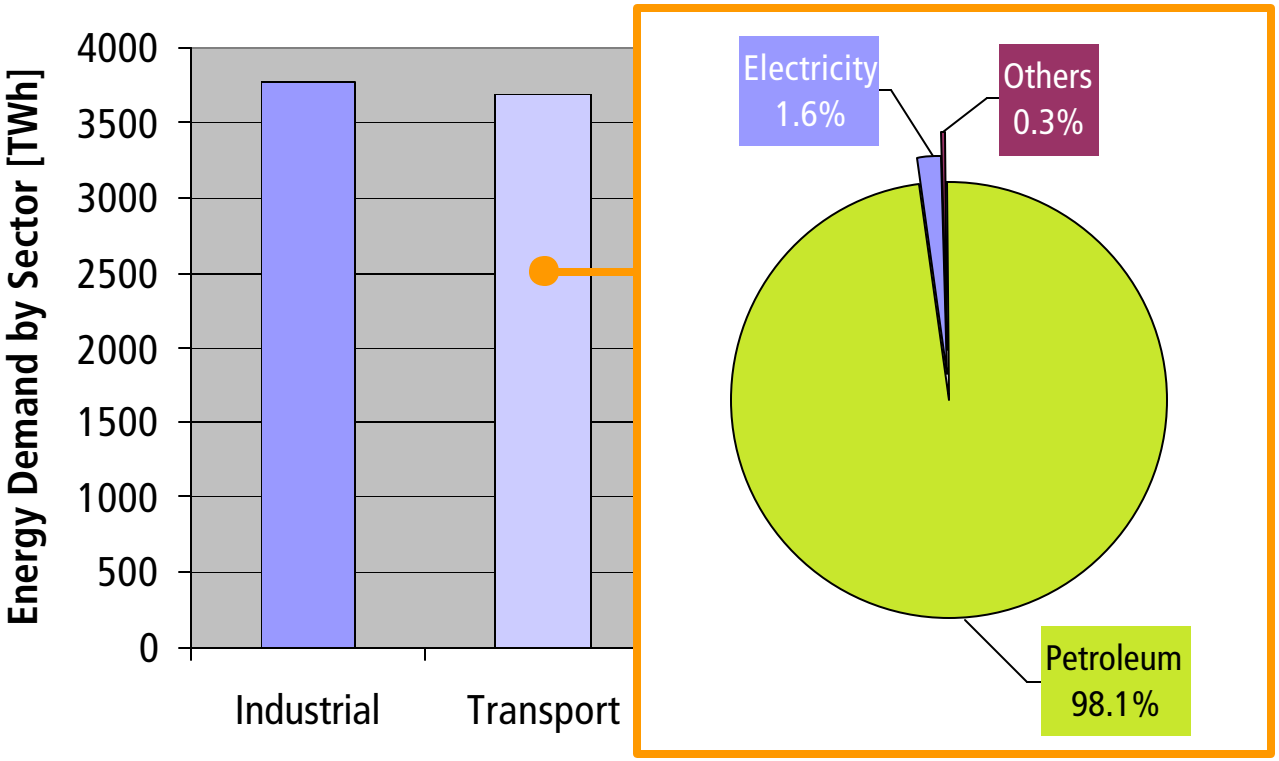

EFC

- **Portable power supply**
  - Emergency backup
  - Notebook, cellular, PDA etc.


NEC


Coleman

Primary energy demand (EU-15, 2000)



- Electricity: 18% (2,572 TWh)
- Petroleum for transportation: 25.5% (3,622 TWh)

Source: IEA, Energy Balances of OECD Countries 1999-2000, page II.47, OECD (ed.), Paris, 2002

Hydrogen/fuel cell vehicle announcements

Car manufacturers

GM/Opel:	50,000 – 100,000 fuel cell vehicles by 2010
Ford:	50,000 fuel cell vehicles by 2010

Source: Industry announcements

Japan

2005 – 2010:	50,000 FC vehicles	2,100 MW_{el} stationary FC
2010 – 2020:	5 million FC vehicles	10,000 MW_{el} stationary FC

Source: NEDO/WE-NET

FC = fuel cell

Major hydrogen/fuel cell initiatives

International

- International Partnership on Hydrogen Energy (IPHE)
- UNEP/GEF Fuel Cell Bus Project

Europe

- 2002: High Level Group for Hydrogen and Fuel Cell (HLG)
- 2004: European Hydrogen and Fuel Cell Technology Platform
- ‚**Hypogen**' und ‚**Hycom**' (EUR 2.8 billion up to 2015)
- Clean Urban Transportation Energy (CUTE)

Americas

2003: US ‚Freedom Car'/‚Hydrogen Fuel' Initiative (US$ 1.7 billion)

2004: ‚Hydrogen Highways' (e.g. CA/USA, FL/USA, BC/Canada)

Asia

- WE-NET
- 2003: Japan Fuel Cell & Hydrogen Demonstration Project (JHFC)

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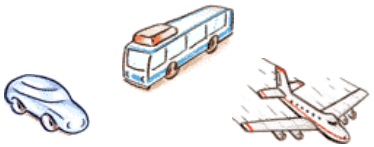
Technology pathway "Transportation"



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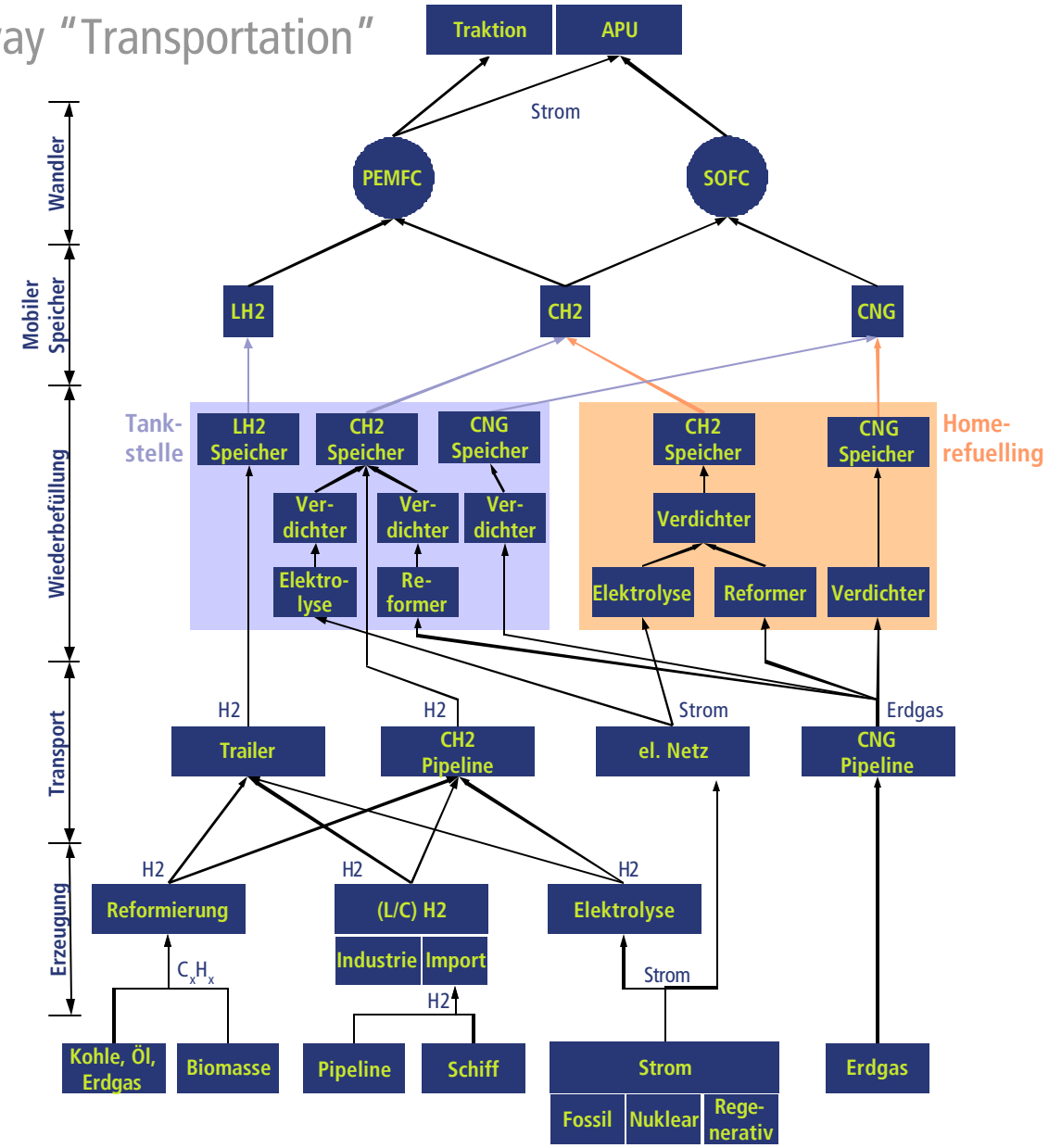

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Well-to-wheel analysis

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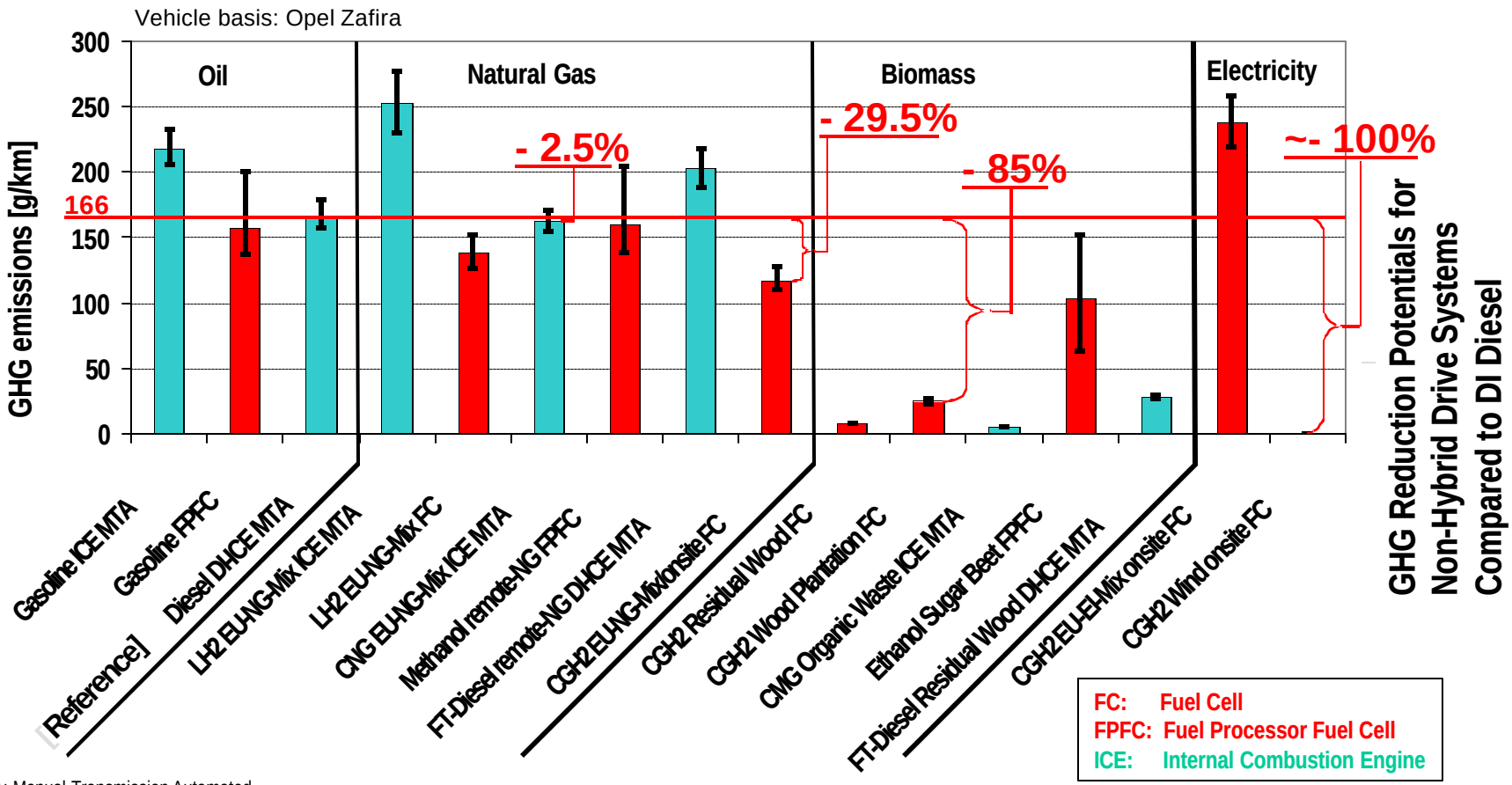

MTA: Manual Transmission Automated
ICE: Internal Combustion Engine
DI-ICE: Direct Injection Internal Combustion Engine
FPFC: Fuel Processor Fuel Cell
FC: Fuel Cell

Source: General Motors Well-to-Wheel Study; LBST, BP, Exxon, Shell, Total, 2002; available at: www.LBST.de/ gm-wtw/

Renewable energy potentials in Europe

Biomass	**600 TWh_e/yr**	Europe w/o former USSR [Kaltschmitt 2001]
Geothermal	**2,030 TWh_e/yr**	EU-30 [Bjornsson 1998]
Hydro	**584 TWh_e/yr**	470 TWh_e/yr inland EU-15 [LTI 1998] 114 TWh_e/yr offshore UK [Petroncini 2000]
Photovoltaic	**8,976 TWh_e/yr**	891 TWh_e/yr roof 3,356 TWh_e/yr former agricultural land 4,729 TWh_e/yr other land (arid etc) EU-30 LBST derived from [Klaiß 1992]
Solar thermal	**4,644 TWh_e/yr**	EU-30 LBST derived from [Klaiß 1992]
Wind	**4,000 TWh_e/yr**	1,000 TWh_e onshore 3,000 TWh_e offshore

Hydrogen supply capability

Million mid-sized fuel cell vehicles supplied by SPS via electrolysis:

Scenario size [GW]	0.5	5	10	50	100	150	500
CGH_2	0.52	5.2	10	52	105	157	523
LH_2	0.46	4.6	9	46	91	137	456

SPS Rule-of-Thumb

For each GW_e of installed supply capacity some one million cars could be powered.

SPS data derived from LBST et al.: Earth & Space-Based Power Generation Systems – A Comparison Study, 2004

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Hydrogen production vectors

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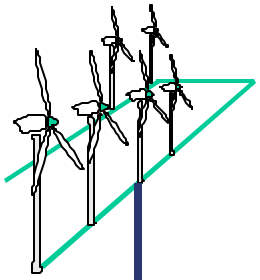

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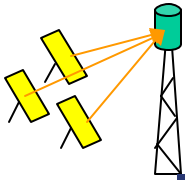
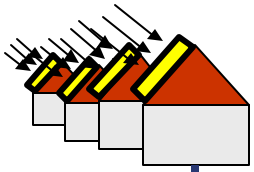
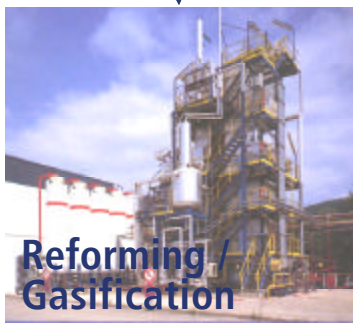




Natural Gas

Coal



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Hydrogen production – Energy effort

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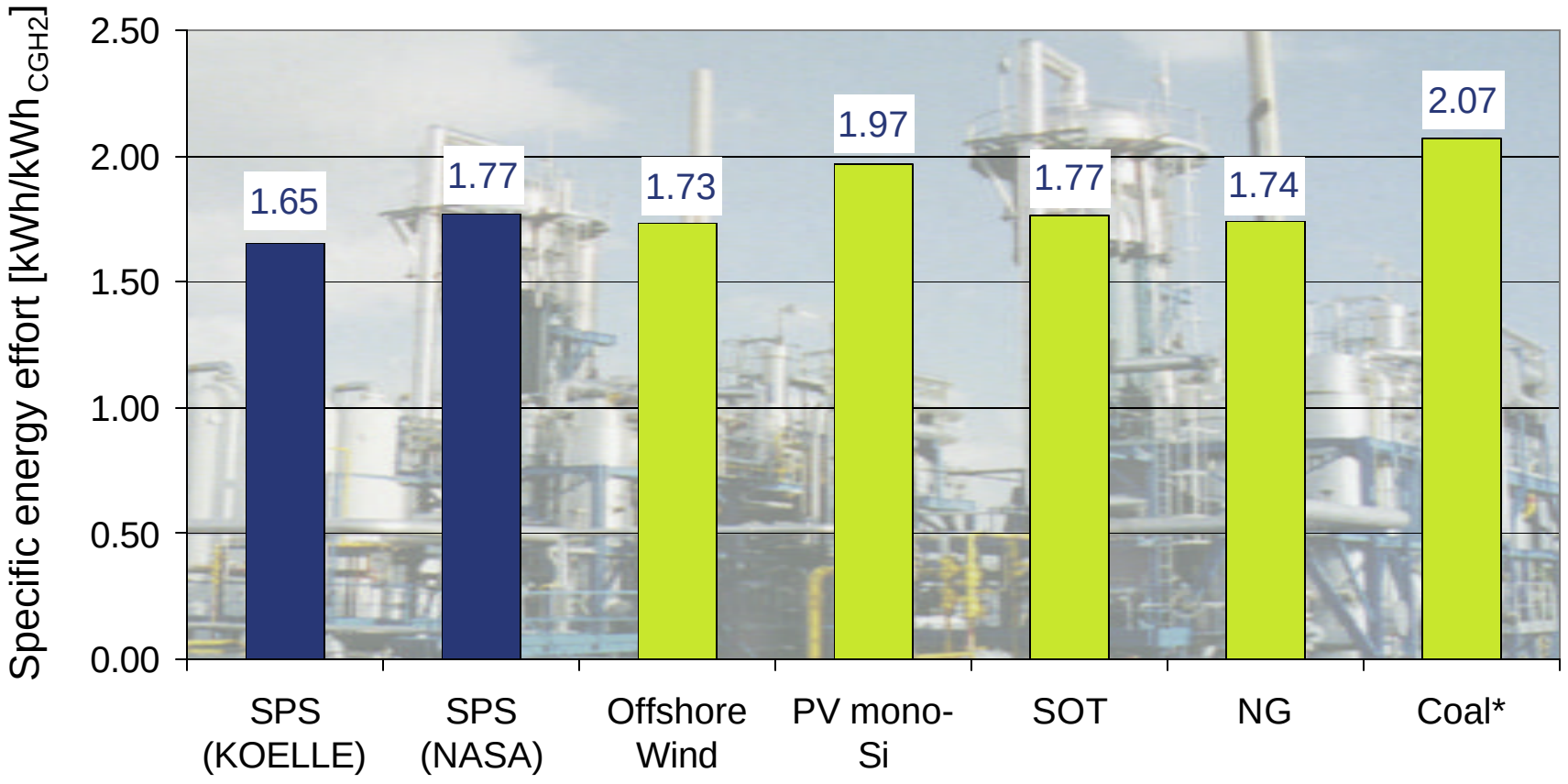

*without CO_2 capture/sequestration

SPS data derived from LBST et al.: Earth & Space-Based Power Generation Systems – A Comparison Study, 2004

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Hydrogen production – Greenhouse gas emission

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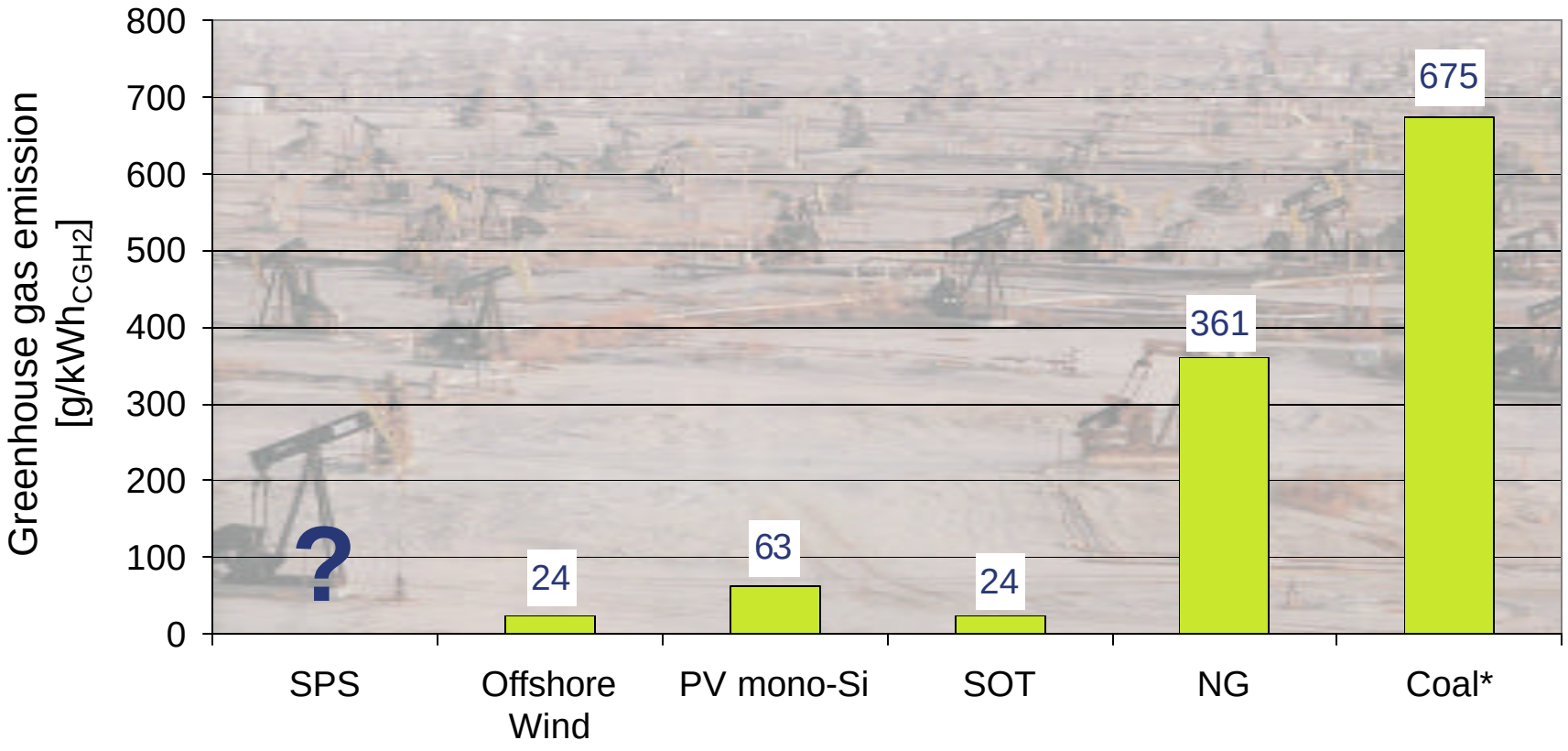

*without CO_2 capture/sequestration

SPS data derived from LBST et al.: Earth & Space-Based Power Generation Systems – A Comparison Study, 2004

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Hydrogen production costs

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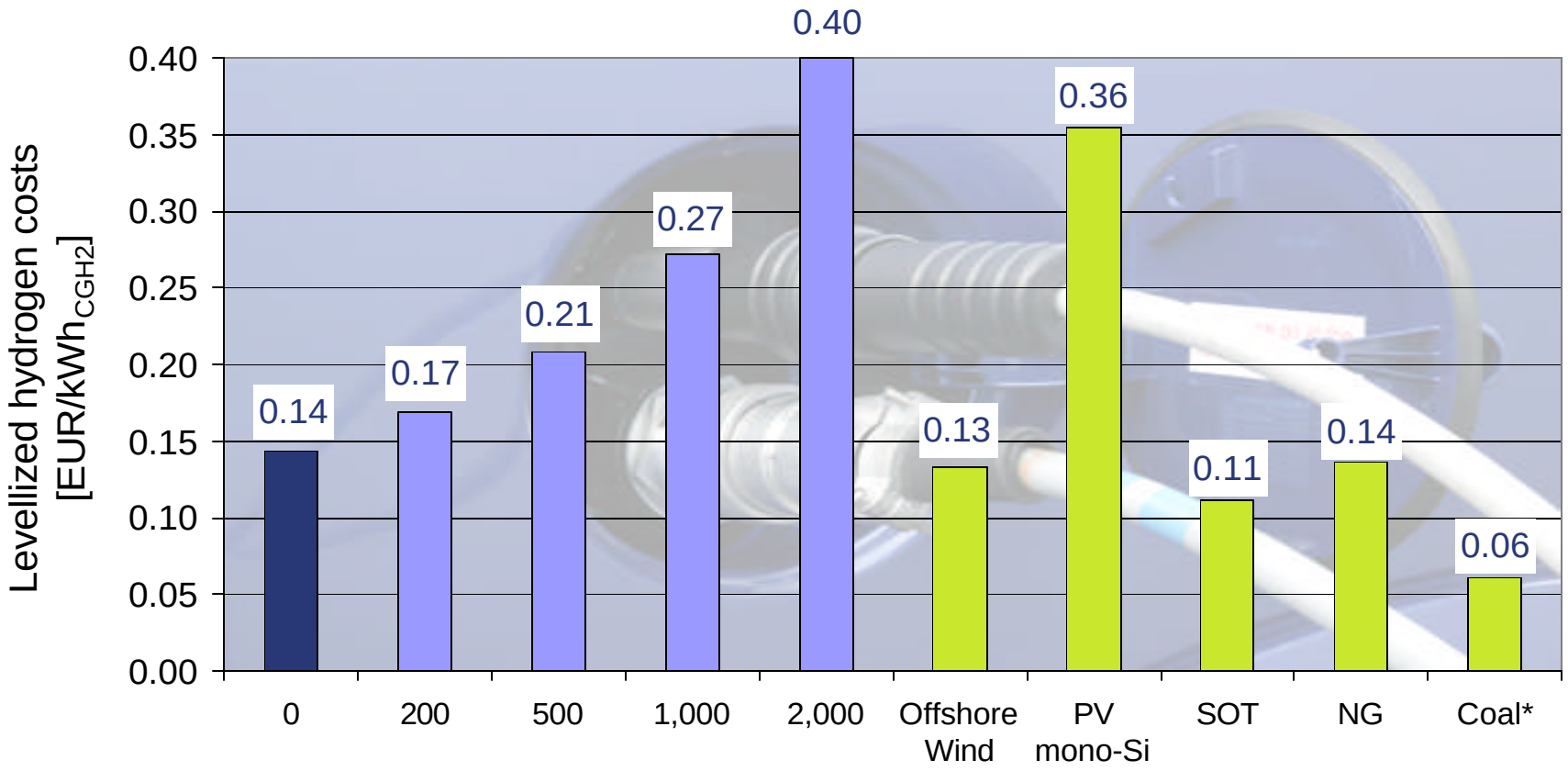

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SPS data derived from LBST et al.: Earth & Space-Based Power Generation Systems – A Comparison Study, 2004

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Conclusion

- Supply of hydrogen as transportation fuel is a **potentially attractive target market**
- Depending on the underlying assumptions, the **renewable energy potential in Europe could be insufficient** to provide both power and transportation fuel
- SPS attributed **energy effort** for H_2 production for transportation is comparable to other renewable supply options
- SPS attributed release of **greenhouse gas emissions** are subject for further research
- SPS **production costs** significantly depend on the cost of space transportation. A cost advantage of SPS over other H_2 production options is NOT necessarily given

Thank you!

Websites provided by L-B-Systemtechnik

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Information on hydrogen and fuel cells:
www.HyWeb.de **www.HyNet.info**

Information on fossil fuel resources:
www.EnergyShortage.com

Information about fuel cells:
www.FuelCellPark.com

Hydrogen und fuel cell vehicle overview:
www.H2Cars.de

Information on hydrogen projects:
www.H2Guide.de