Workshop on Physics and Chemistry of Climate Change

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A sustainable energy future: what can science do?

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World Primary Energy Supply (2004)

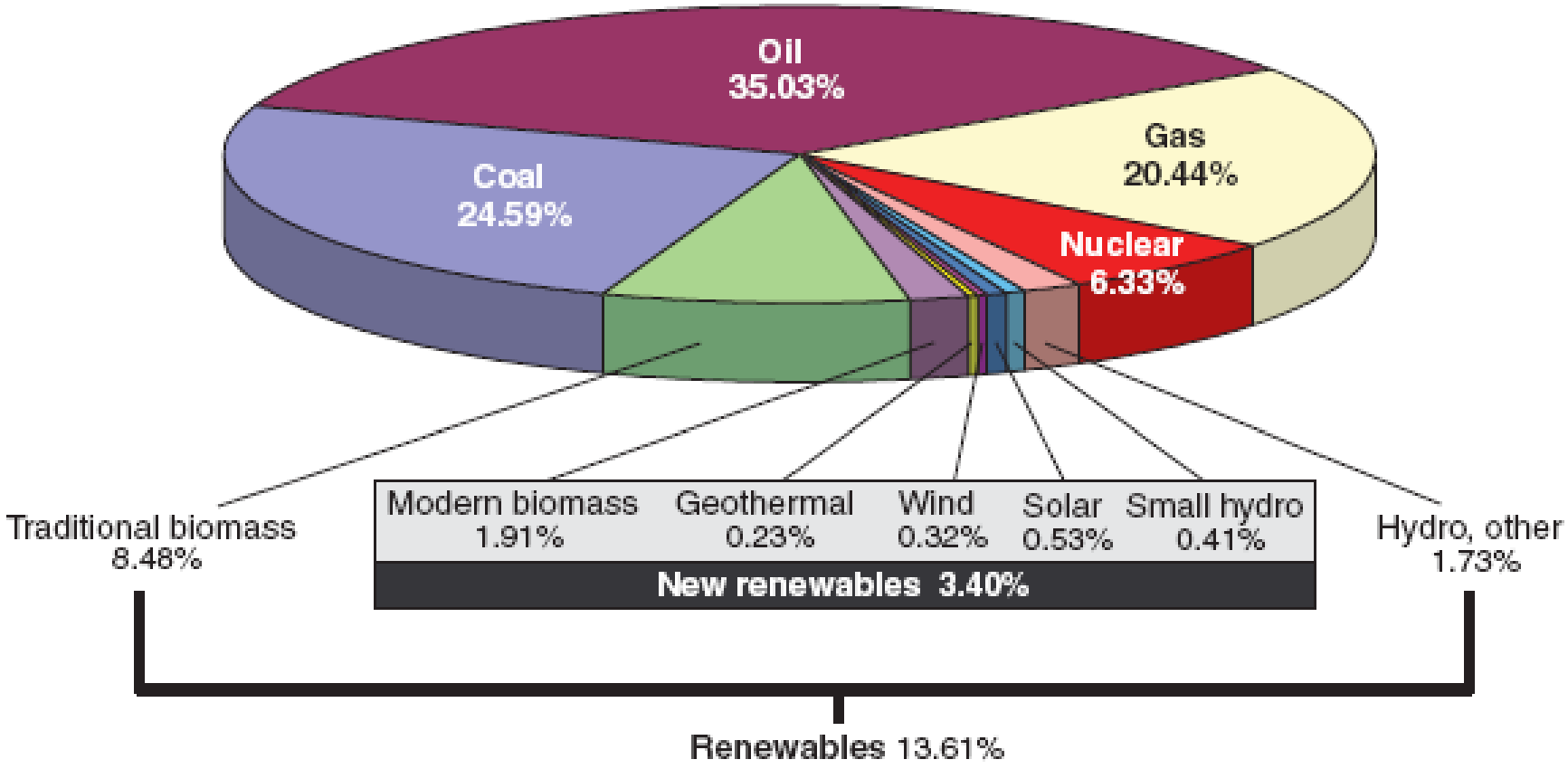
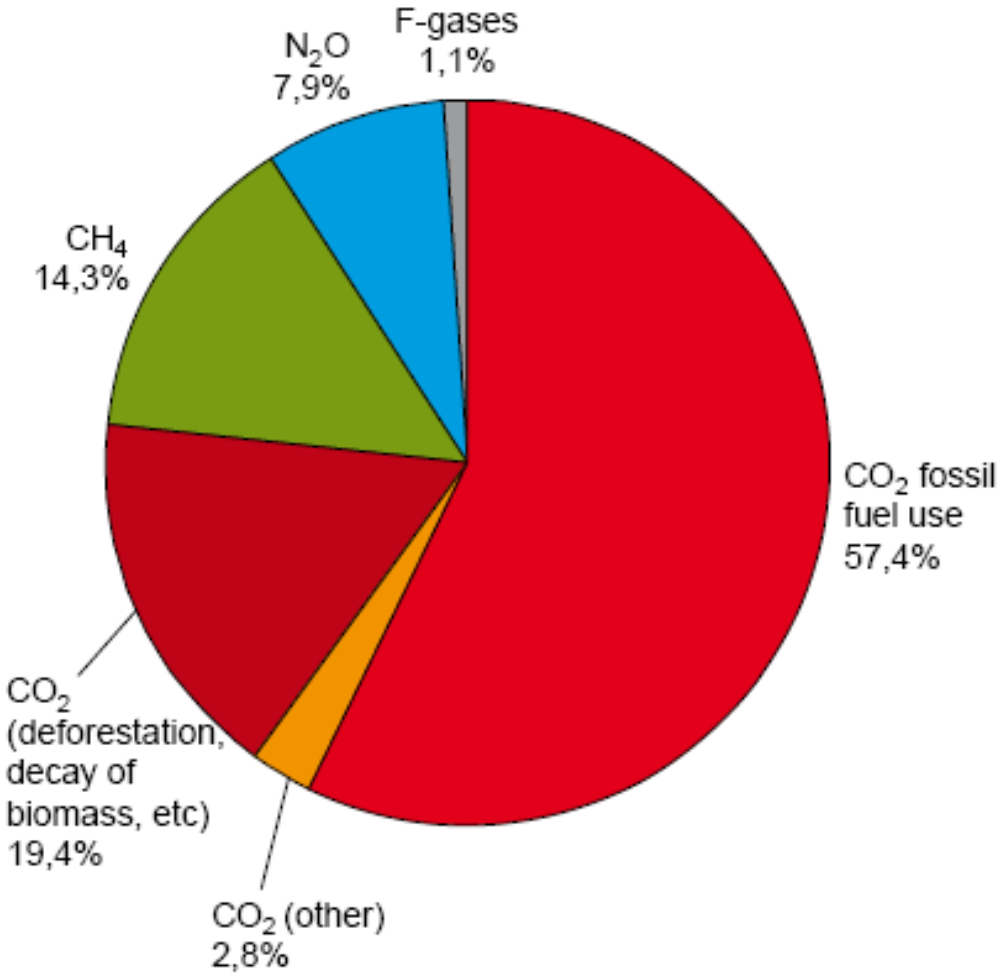


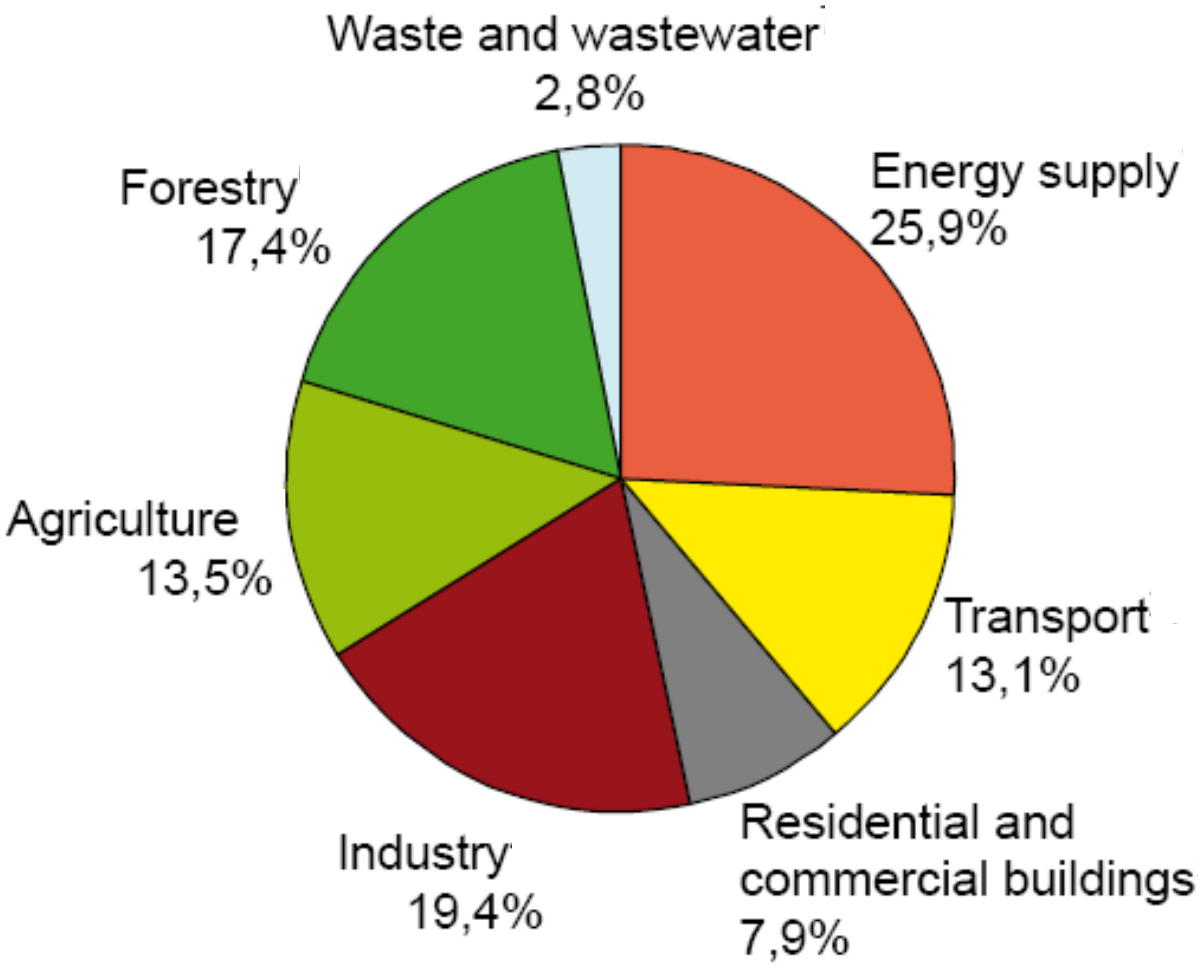
Fig. 1. World total primary energy supply 2004, shares of 11.2 billion tons of oil equivalent, or 470 EJ (*15*, *16*).

Global anthropogenic greenhouse emissions in 2004



Source: IPCC, 2007

GHG emissions by sector in 2004



Source: IPCC, 2007

Table 4.2 Energy R&D opportunities

Technologies	R&D	Demonstration
Transport sector		
Hybrid vehicle	■	
Hydrogen fuel cell vehicle	■	
Fuel – ethanol (cellulosic)	■	■
Fuel – Hydrogen	■	■
Industry sector		
Materials production process	■	■
Materials/product efficiency	■	■
Feedstock substitution	■	■
Carbon dioxide capture and storage	■	■
Buildings and appliances sector		
Heating and cooling technologies	■	
Building energy management systems	■	■
Lighting systems	■	■
Reduce stand-by losses		■
Building envelope measures	■	■
Solar heating and cooling		■
Power generation sector		
Biomass	■	■
Geothermal	■	■
Wind (onshore and offshore)		■
Solar photovoltaics	■	■
Concentrating solar power	■	■
Ocean energy	■	■
Advanced steam cycles (coal)		■
Integrated gasification combined cycle (coal)	■	■
Fuel cells	■	■
Carbon capture and storage + Advanced steam cycle with flue-gas separation (coal)	■	■
Carbon capture and storage + Advanced steam cycle with oxyfueling (coal)	■	■
Carbon capture and storage + Integrated gasification combined cycle (coal)	■	■
Carbon capture and storage + Chemical absorption flue-gas separation (natural gas)	■	■
Nuclear – Generation II and III	■	■
Nuclear – Generation IV	■	■

■ indicate significant opportunities and needs.

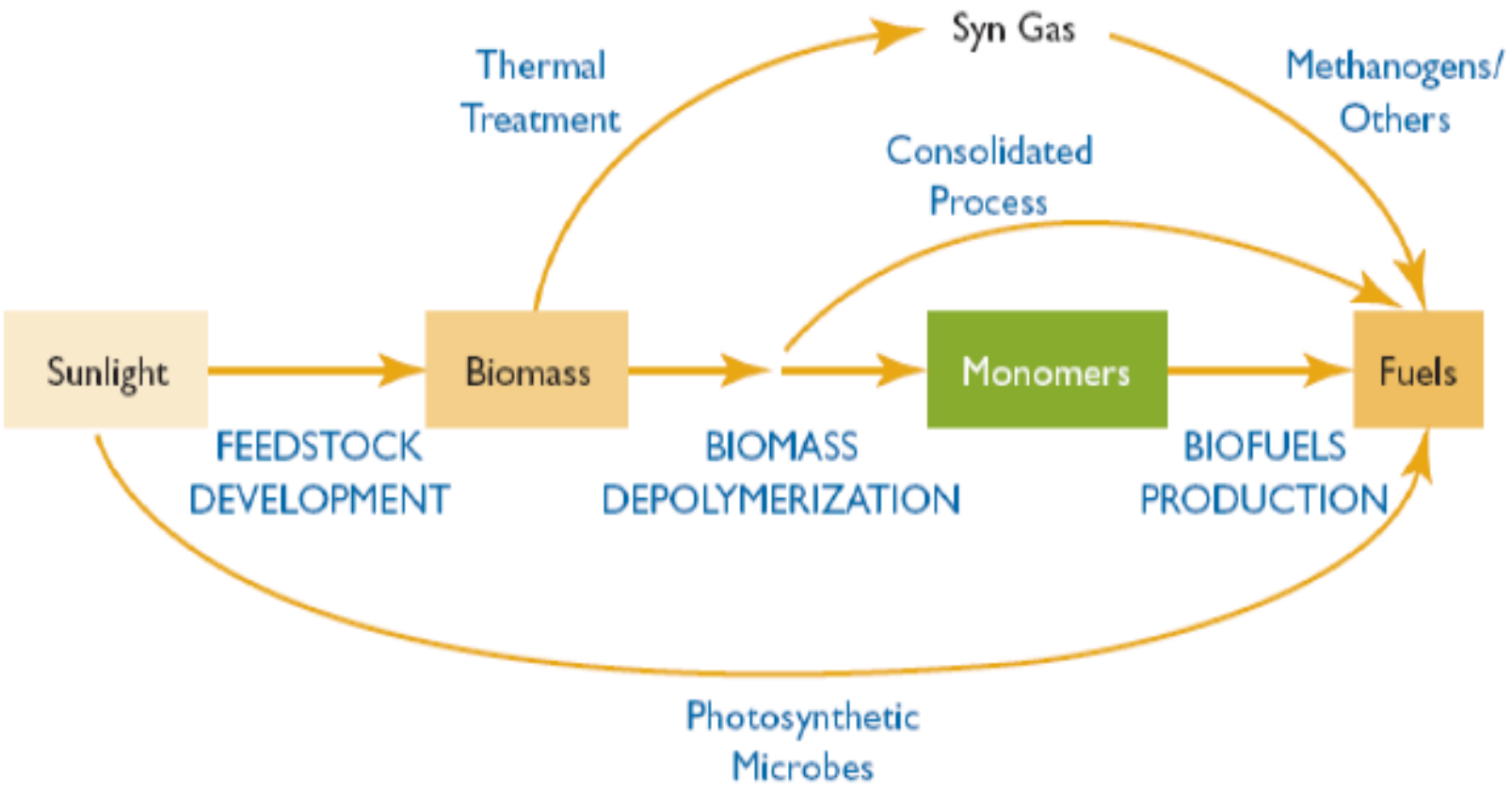
■ Indicate that the technology under scrutiny would benefit from further R&D and/or demonstration.

Source: IEA, 2006.

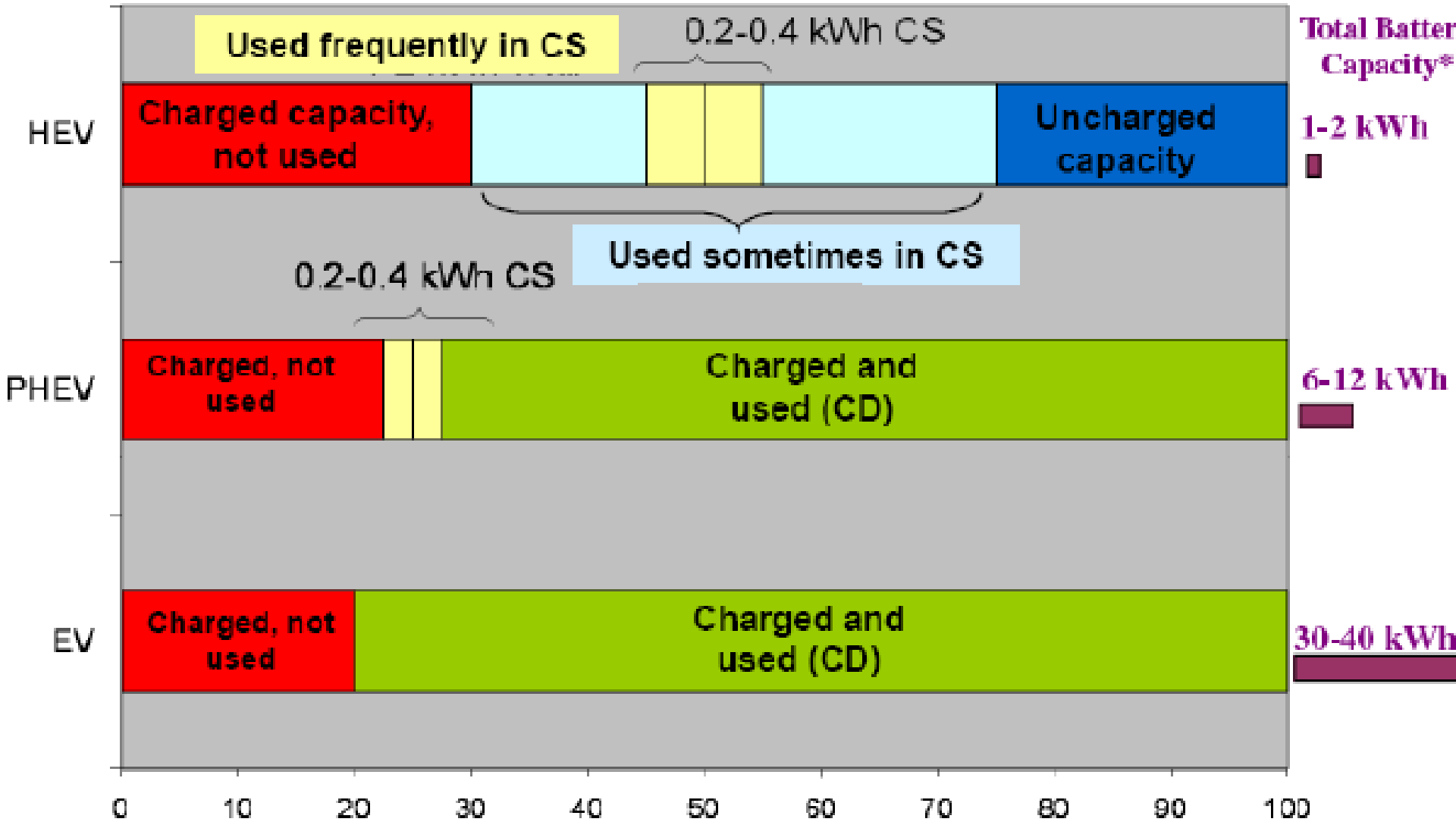
Examples of where research is needed

- efficiently extracting useful energy from the lignocellulosic part of biomass,
- increasing biomass yields by boosting photosynthetic water and nutrient efficiencies through genetic engineering,
- applying nanotechnology and/or using new materials to improve the energy conversion efficiency of photovoltaic devices,
- developing solid-state storage options for hydrogen and
- energy storage device.

Biomass fuel production



Battery Usage in EVs, HEVs, and PHEVs



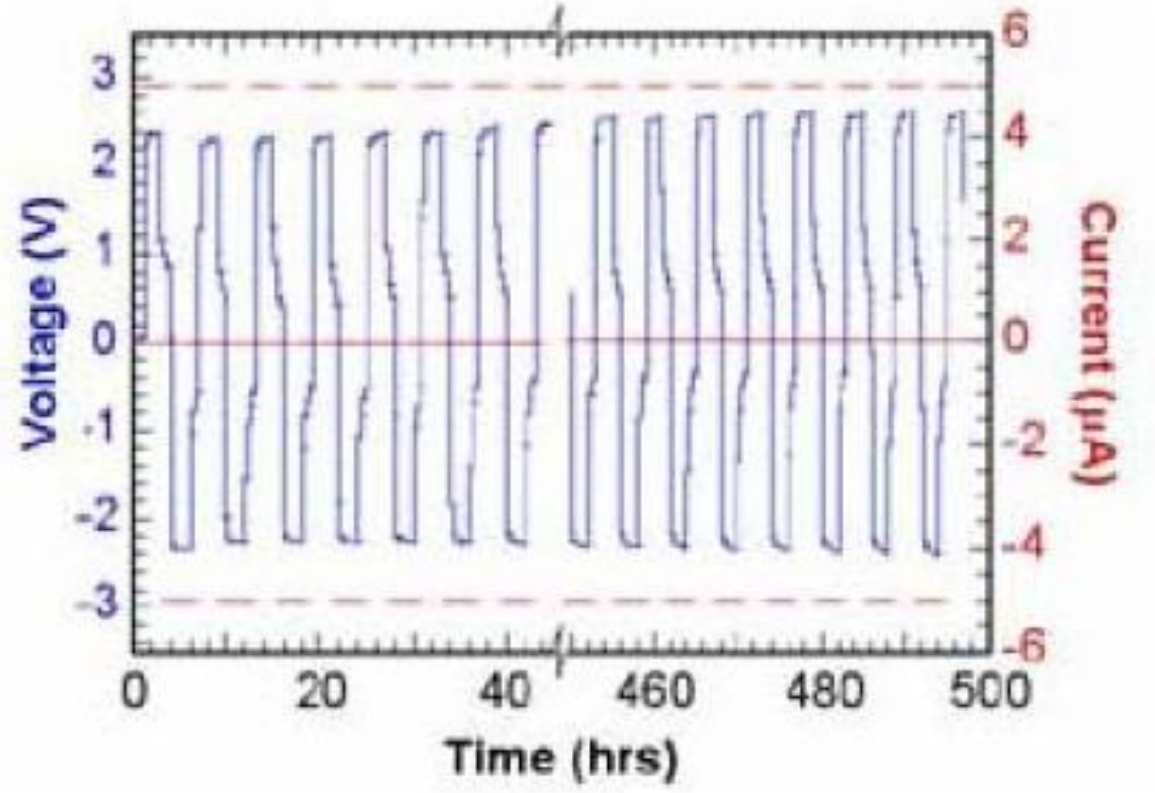
CD: Charge Depleting

CS: Charge Sustaining

*Battery capacity for a midsize car

A lithium – metal battery material with a dry, block copolymer separator shows promise. (Nitash Balsara)

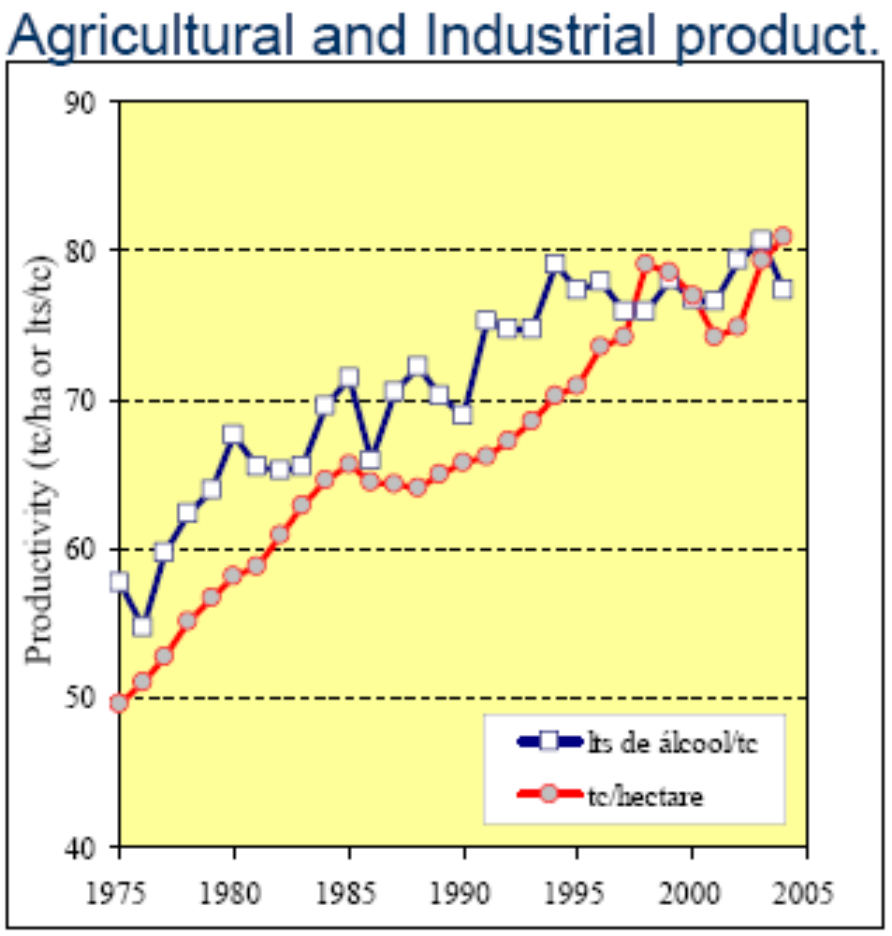
Latest results of prototype ~ 1000 deep discharge cycles and ***no*** sign of degradation. Energy density initial target: 2x Li-ion



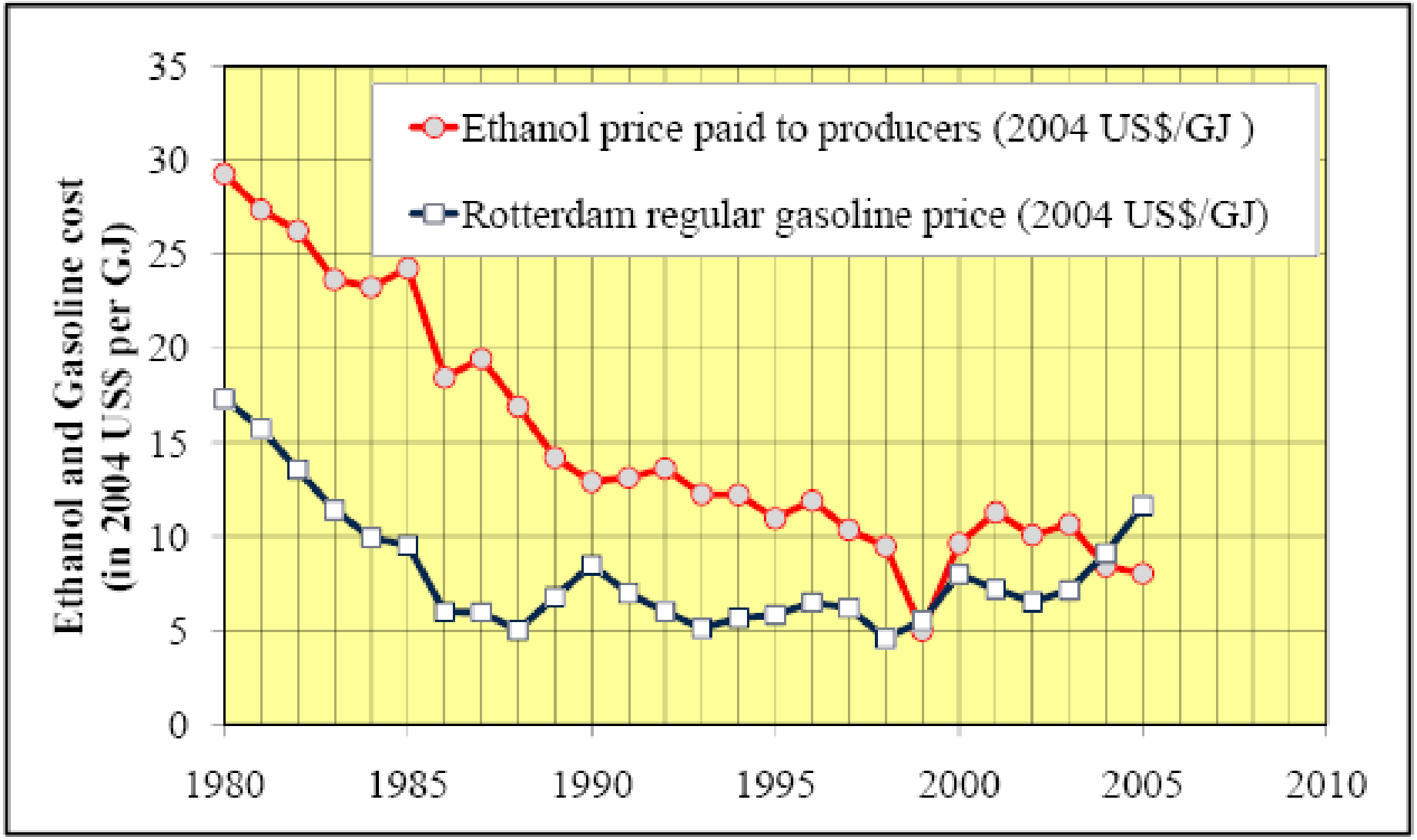
ENERGY STORAGE

	MJ/kg	KWh/kg
Crude oil	50	16.7
Lead acid batteries	0.1	0,03
Lead oxide/sulfuric acid batteries	<0.7	<0,23
Present lithium – ion batteries	0.5	0.16
Limit of lithium ion batteries	3	1
Capacitor	2	0,67
Superconducting electric magnets	4	1.3
Present magnetic storage	0.01	0,003
Present air batteries	1.3	0,43
Theoretical limit zinc air batteries	5.3	1.9
Theoretical limit of al or Li batteries	32-43	10,6-14.3
Hydrogen (700 bars)	6	2
Gasoline	34	11.3
Fly wheels	100	33.3

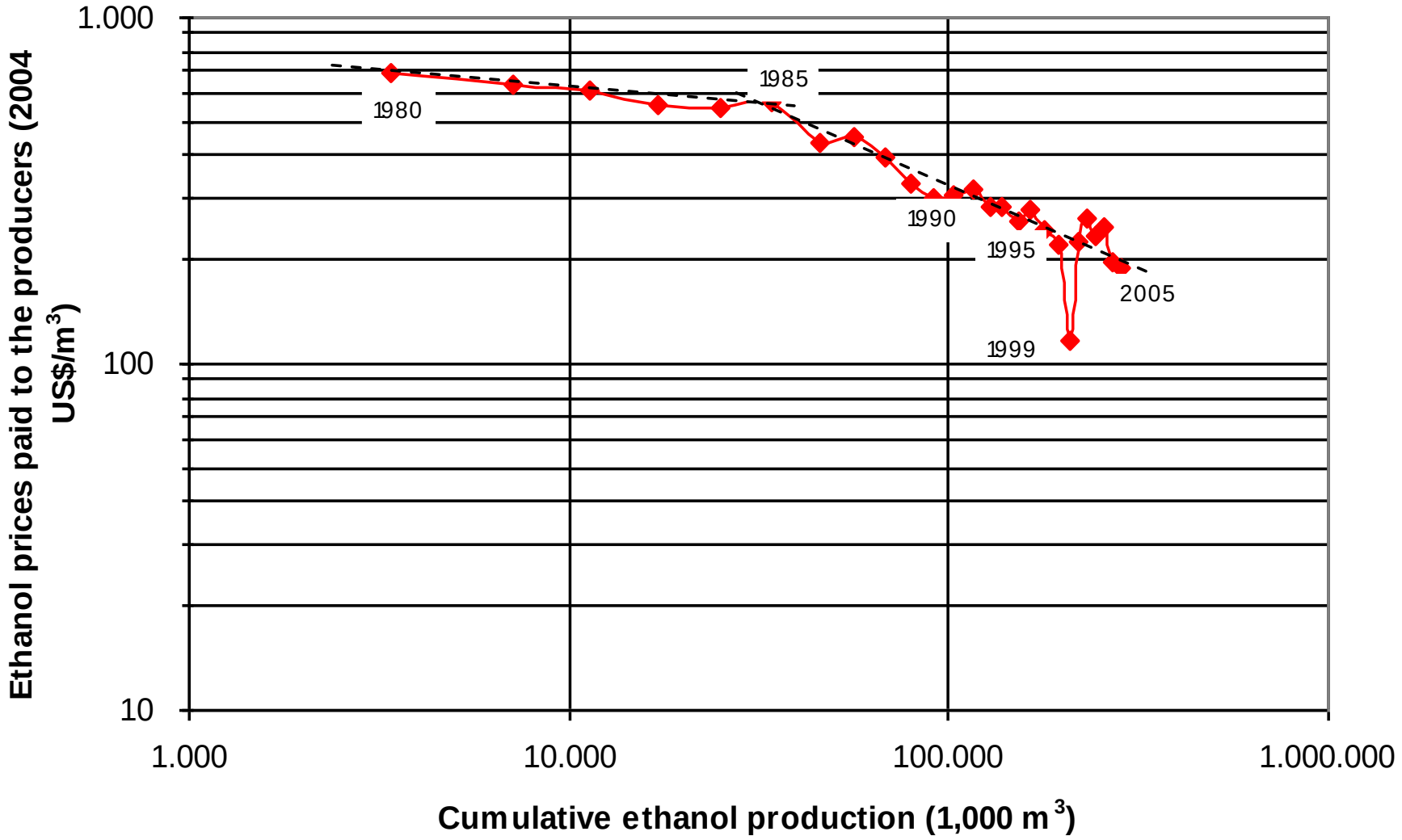
Increase in productivity through R&D



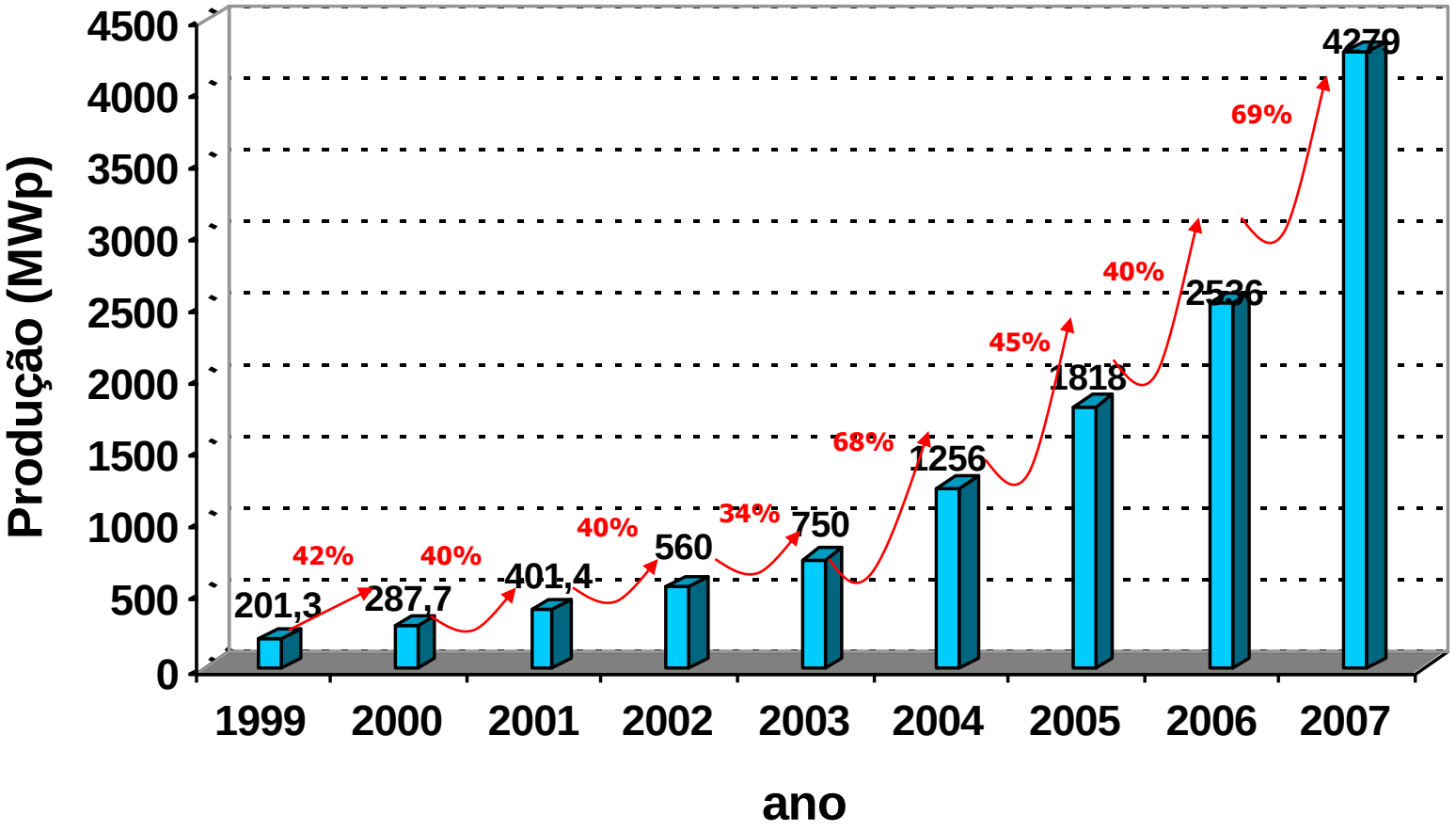
Ethanol costs x Gasoline



Source: Goldemberg, 2005


Ethanol Learning Curve
1.000
100
10
1.000
10.000
100.000
1.000.000
1980
1985
1990
1995
1999
2005
Ethanol prices paid to the producers (2004 US$/m3)
Cumulative ethanol production (1,000 m3)

Produção de células solares 1999 - 2007



Photon International, 3, 2006; Cell and Module production survey 2005, pp 100-125
Photon International, 3, 2007; Market survey on global solar cell and module production 2006, pp 136-166
Photon International, 3, 2008; Market survey on global solar cell and module production 2007, pp 140-174

Learning Curves for PV

Fonte: Gregory Nemet, University of Wisconsin – Madison, Learning Curves for PV, International Energy Agency, June 2007

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