

School of Engineering

Introduction to Reversible Energy Storage

Mark Sandford

<https://www.youtube.com/watch?v=ga4L1w66AbU>

https://www.youtube.com/watch?v=CxS7XeIh_i4

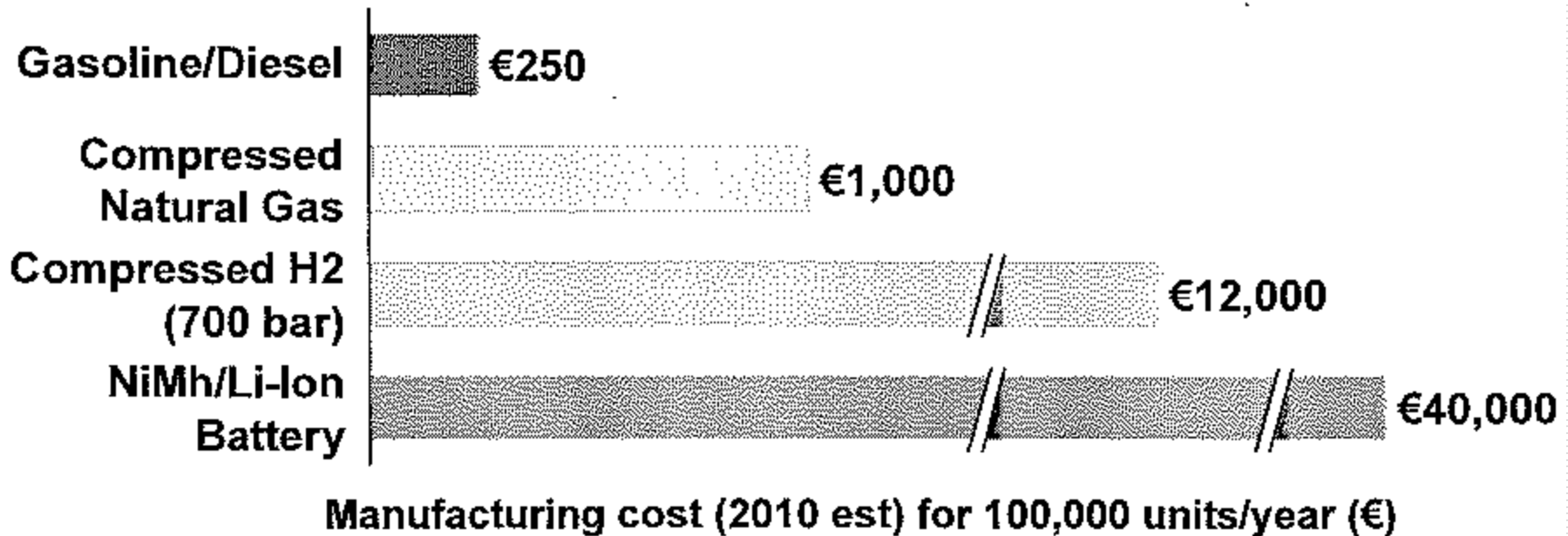
Storage challenges

Current fuels

- ❑ Liquid hydrogen fuels are dense and cheap
 - ❑ Current vehicles travel 500-1000km before refuelling
 - ❑ Refuelling rate ???? litres/min
= over 20 megawatts
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In vehicle energy storage system costs

Onboard Fuel Tank System Cost (550 km range)



Alternative energy storage systems

Energy Storage Device	Energy Density	Power Density
	Wh/kg	kW/kg
Lithium Ion	150-200	1
NiMH	<100	0.8
Zebra	~90	~0.2
Bipolar Lead Acid	30	
Super Capacitors	5	<5
Lithium Ion Polymer	100 to 155	0.1 – 0.3

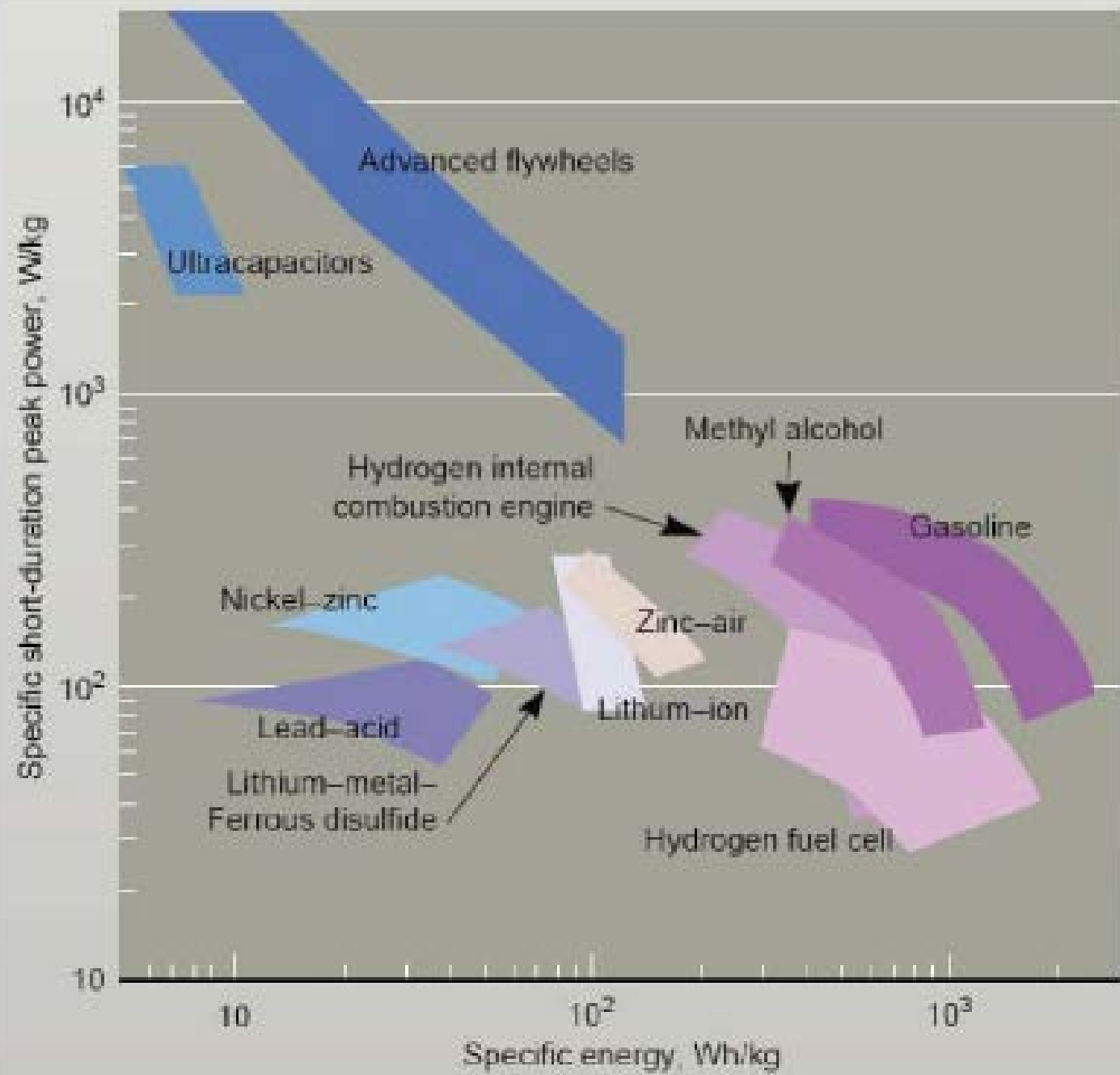
Energy Storage Device	Energy Density	Power Density
	Wh/kg	kW/kg
Flywheel	10	~ 4
Liquid N2	215	
Air at 300 bar	180	
H2	33,500	
Gasoline	12,000	

Reversible Energy Storage

- ☐ Ideally energy storage systems will be reversible
 - ☐ Why ?
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Reversible Energy Storage

- Ideally energy storage systems will be reversible
 - Why ?
 - Recover kinetic energy
 - Allow ICE operating point to be independent of vehicle traction requirements.
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Selection considerations

- ☐ Energy density
 - ☐ Power density
 - ☐ Cell voltage
 - ☐ Capital cost
 - ☐ Complexity of battery management
 - ☐ Cycle life limitations
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Selection considerations

- ☐ Depth of discharge
 - ☐ Charge acceptance
 - ☐ De-rating with load
 - ☐ Temperature range
 - ☐ Self discharge
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Lead Acid

- Each cell
 - One plate – lead
 - Other plate – lead dioxide
 - Sulphuric acid electrolyte
 - Typically 2 volts per cell
 - Cell failure usually open circuit
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Lead acid Pros and cons

- ❑ Low initial cost
 - ❑ Low energy density
 - Measured in amp hours (@12v)
or watt hours
 - ❑ High/Med power density
 - ❑ Low cycle life
 - Typically 200 cycles @ 50% DOD
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Valve regulated lead acid

- Sealed construction –
 - Safety
 - No 'drying out'
 - Compressed plate construction
 - Plates do not support themselves
 - Better vibration resistance
 - Improved elec density/performance
 - Expensive
 - May require thermal management
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Nickel Metal Hydride - Pros

- High/med energy density
 - High power density
 - Use in current hybrid vehicles
 - Good cycle life
 - Typ 800 cycles @ 80% DOD
 - Ok to manage
 - Temp and deep discharge management required
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NI-MH cons

- ☐ Expensive
 - ☐ Low cell voltage 1.2v
 - ☐ Must not deep discharge
 - ☐ Poor low temp performance
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Lithium Ion

- High energy density
 - High power density
 - Costs closing in on NiMH technology
 - Complex battery management
 - Must not overcharge
 - Nasty failure modes for some chemistries
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