Summary and conclusions about electrical storage

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- **Direct storage systems (no conversion)**
  - Supercaps
  - SMES
- **Power – energy discoupled systems**
  - Redox-flow batteries (Hybrid with zinc)
  - Compressed air centralised
  - Flexible hydro-pneumatic storage
  - Hydro-pumping
  - Hydrogen based storage
- **Mechanical energy storage**
  - Flywheels
- **Battery systems**
  - Lead/acid
  - Ni-Mh, Ni-Cd
  - Lithium-ion
  - Na/S, Na/NiCl

Electrical double layer capacitor

- **Advantages**

Long cyclic life

High power density

Permanent SOC indication

Same behaviour in charge and discharge

- **Drawbacks**

Cost

Very low energy density

High self discharge

Need of electronics due to variable tension

Safety?

- **R&D**

Cost reduction by
- **use of cheaper materials**
- **mass production**

Assessment of recycleability

Increase of energy content

Source Batscap

Technology	Characteristics
V/V	Demo., sensitive to V_2O_5 cost
Zn/Br	Demo., bromine bound in complex
V/Br	Higher density than V/V, lower cost, Demo. in 3 years time
Zn/Ce	Lower efficiency, higher price, no Br
Pb	Laboratory research
Bromide/Polysulfide (Regenesys)	Stopped: difficult scaling up due to 2 different electrolytes

Electrolyser, hydrogen storage, fuel cell

- **Advantages**

Low self discharge

Power and energy independent

Possibility to have the fuel cell in a car

- **Drawbacks**

Low system energy efficiency < 40%

Very high cost, complexity

Short proved lifetime

Safety

- **R&D possibilities**

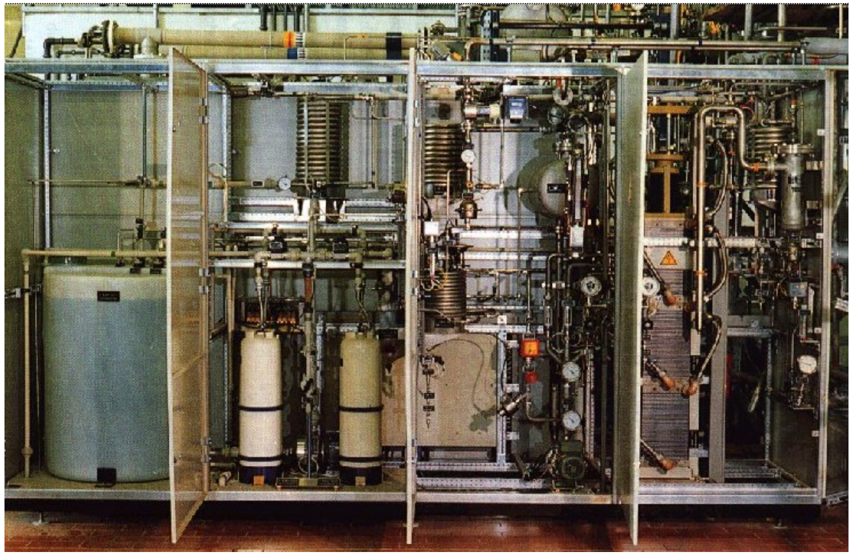
Cost reduction by
- catalyst utilisation reduction
- mass production of fuel cells

Increase of fuel cell lifetime

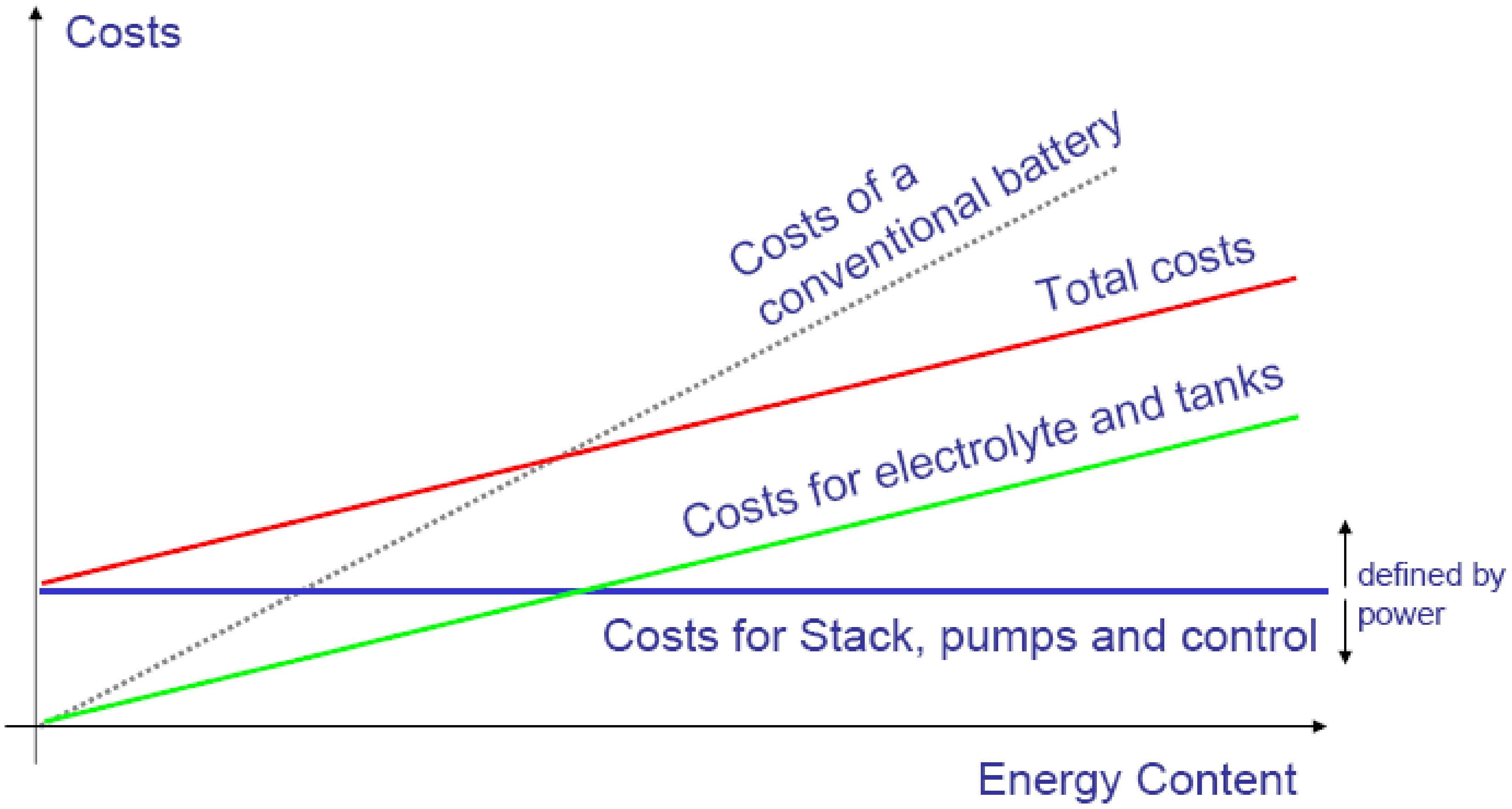
Optimisation of Hydrogen storage

High potential for URFC

Improvement of electrolyser efficiency



Source ZSW


Costs
Costs of a conventional battery
Total costs
Costs for electrolyte and tanks
defined by power
Costs for Stack, pumps and control
Energy Content

- **Conventional (Huntdorf)**

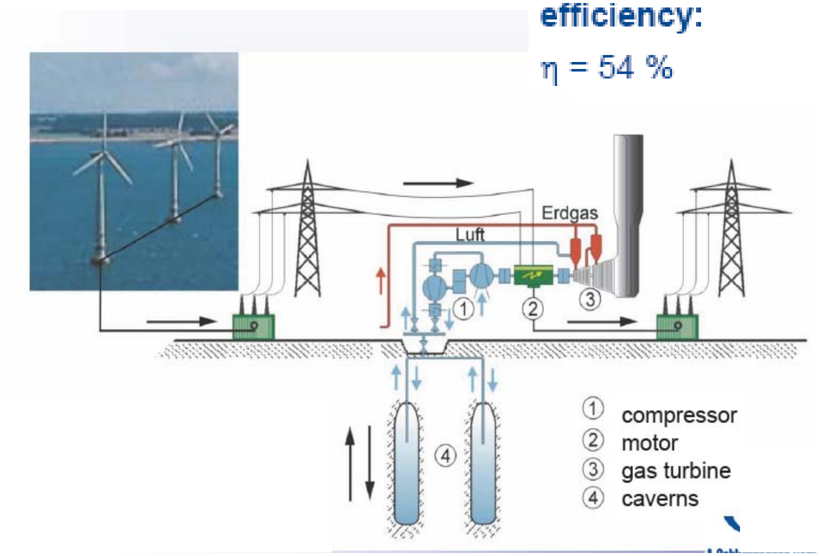
Input:
0,83 kWh elektr. energy
1,56 kWh fossil energy
Output:
1 kWh elektr. energy
efficiency
η = 42 %

- **With heat recuperation (McIntosh)**

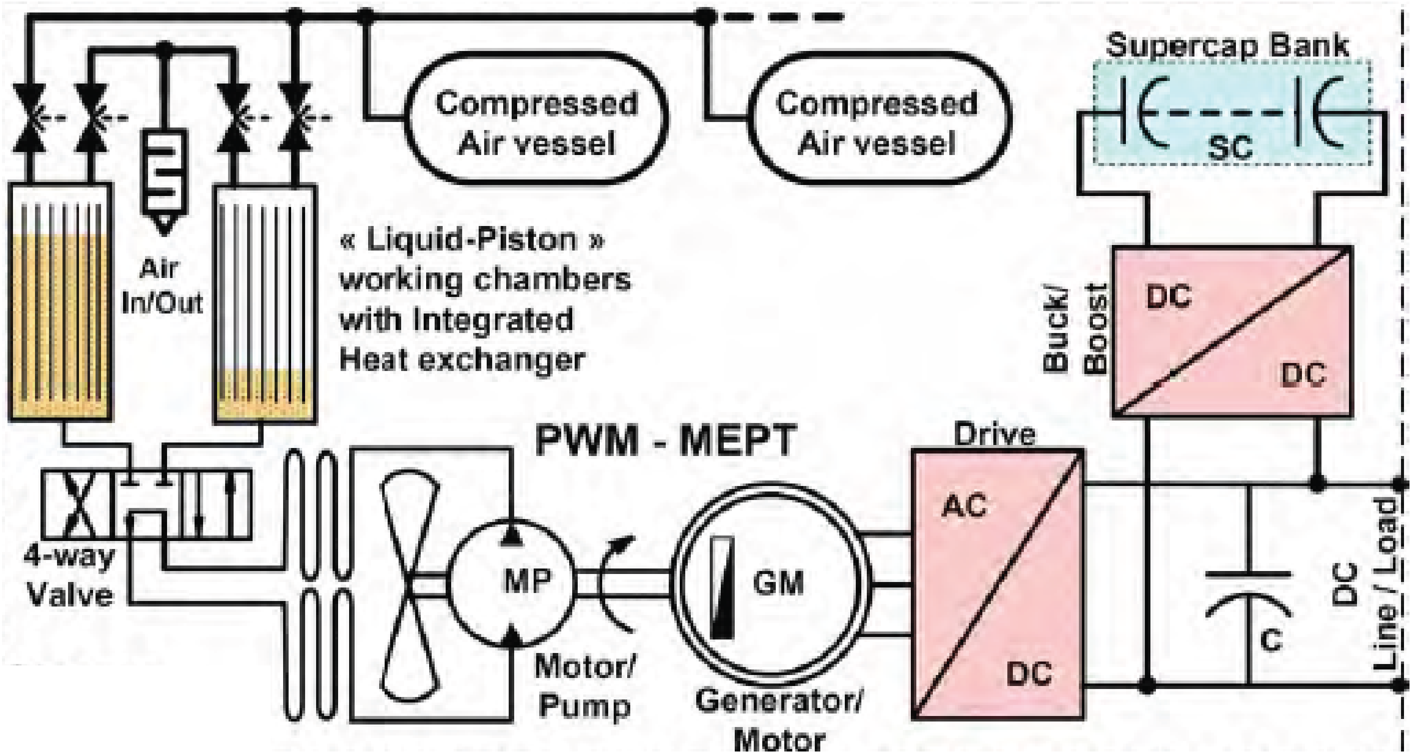
Input:
0,69 kWh elektr. energy
1,17 kWh fossil energy
Output:
1 kWh elektr. energy
efficiency:
η = 54 %

- **With heat storage**

Input:
1,42 kWh elektr. energy
0,00 kWh fossil energy
Output:
1 kWh elektr. energy
efficiency:
η = 70 %



- **Numerous topologies possible depending on application**
- **Efficiency in the range of 50 to 70%**



- **Super fast response – full power range in < 4 seconds!**
- **20-year design life**
- **Can operate continuously**
  - 15 min charge / 15 min discharge
  - 350,000 (100% depth of discharge) cycles in 20 years
  - 1MW system can deliver > 4000 MWh / yr back to the grid
- **It is not about long time (hours) storage: high self discharge**
- **2007, 20MW plant for frequency regulation**
- **HTSC Bearing systems under development**

- **Lead-acid is still the cheapest technology**
- **Ni-Cd is the low temperature solution**
- **Ni-Mh bipolar under test for high power**
- **Li-ion enters the market of PV electricity storage**
- **Na/S is gaining momentum expecially in Japan**
- **Na/$NiCl_2$ flexible sizing demonstrated in buses**

Lead-acid batteries

- **Advantages**

High maturity
Ad-equation to all applications
Low cost
Recycling at 95%
Safety
Medium to high efficiency

- **Drawbacks**

Environmental impact of lead
Sensitive to operating conditions
Sensitive to management strategy
Difficult prediction of state of charge, state of health and failure

- **R&D**

Improved efficiency
Improved lifetime
Reliable indicators

Nickel batteries

- **Advantages**

High power density

Long cyclic life

No maintenance

- **Drawbacks**

Cost
Environmental impact of Cadmium
Self discharge
Medium energy efficiency

- **R&D**

Cost reduction

Performance improvement of NiMH batteries at low temperature

Improvement of recycling

Development of NiZn batteries with high cycleability

Lithium-ion batteries

- **Advantages**

Long cyclic life
High power density
High efficiency
No maintenance
Adapted to all applications

- **Drawbacks**

Cost
Recycling ?
Need of single cell management
Safety ?

- **R&D**

Cost reduction by
- mass production
- use of cheaper materials

Demonstration in RES applications

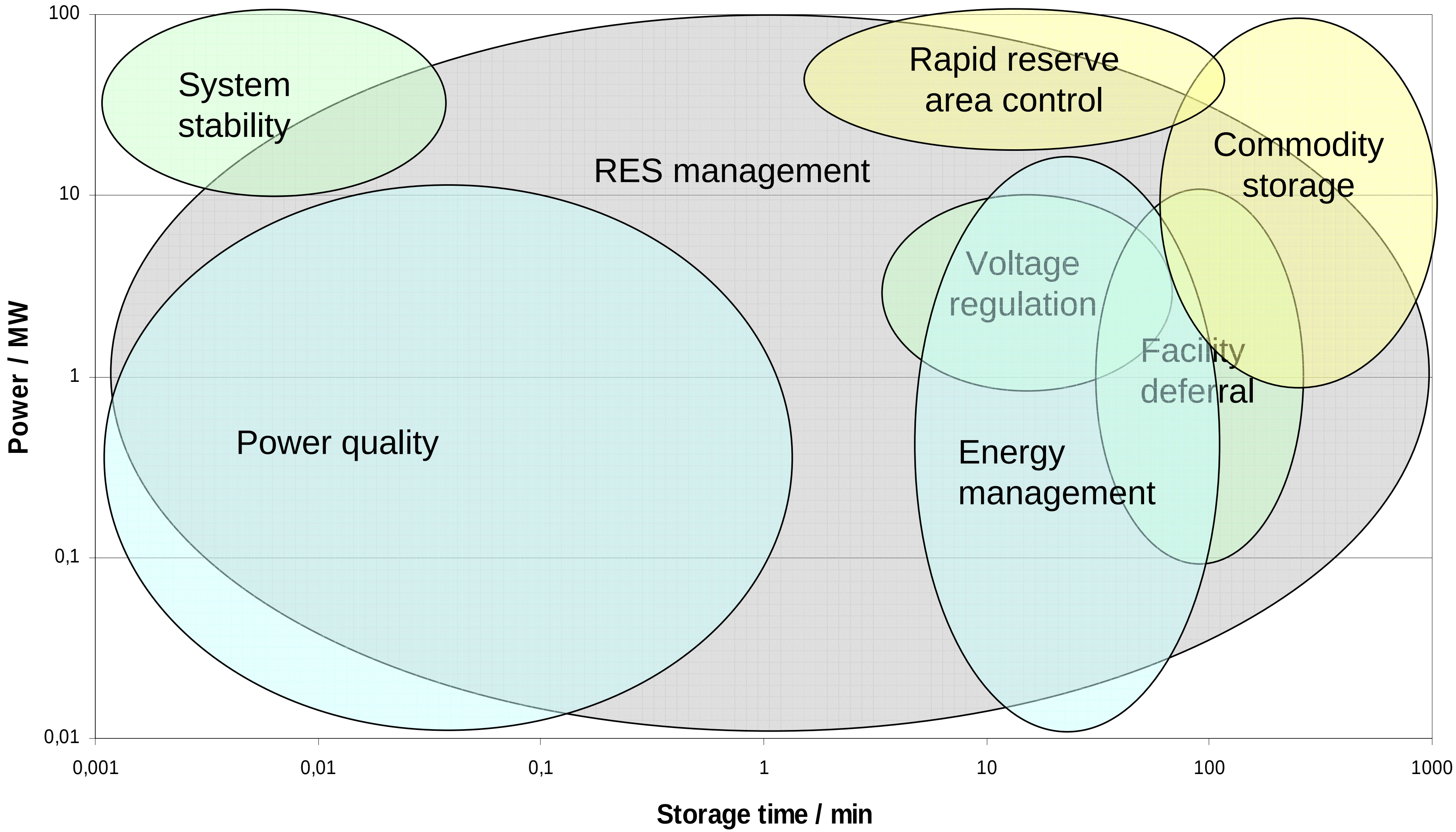
Improvement of recycling

Improvement of safety and BMS

Concluding remarks

Technology	Energy density Wh/kg	Energy efficiency (technology level, cells)	Inv cost €/kWh	Cost of ownership €ct/kWh	Cost of power €/KW	Maturity, remarks
Lead/acid	20-40	85 - 93% (50%SoC)	50-250	10 to 15		Mature, flexible sizing
Ni/Cd		85% (50% SoC)				Mature, only solution at low temperature
Zn/Br	70	77%				Demonstration proceeding
V/V	25	80%	400 (1kW, 4h)		1000 (500 in future)	Demonstration proceeding
V/Br	50	80%	350 (1kW, 4h)		1000 (500 in future)	Demonstration in 3 years
Bipolar NiMh	50	75%				High power demonstration on going
Li-ion SAFT	120	95% +	350 in 2012			
Hydro-pneumatic		50 to 80%				
Flywheel	1	93% (short time)				

Grid-connected storage requirements



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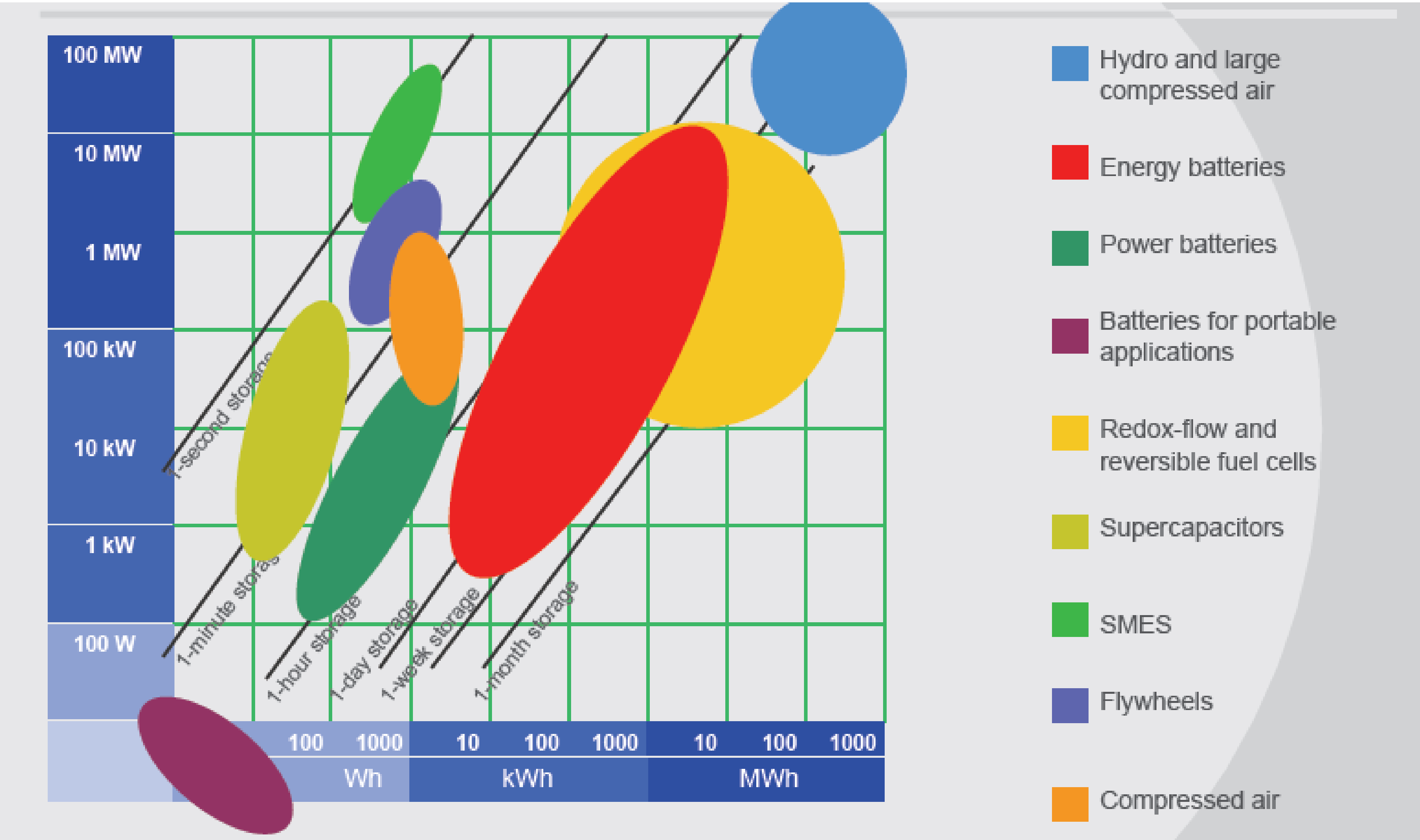
Technologies characteristics



- **Technology manufacturers**
  - Transparency is profitable to renewable energy system
  - Deliver models of your technology for realistic system design and cost calculation (performance and life)
  - Need for standards and use of them
  - Confidency is a key issue

- **System manufacturers, installers, users**
  - An electrical storage system generally does not die, it is murdered
  - Involve manufacturers when designing

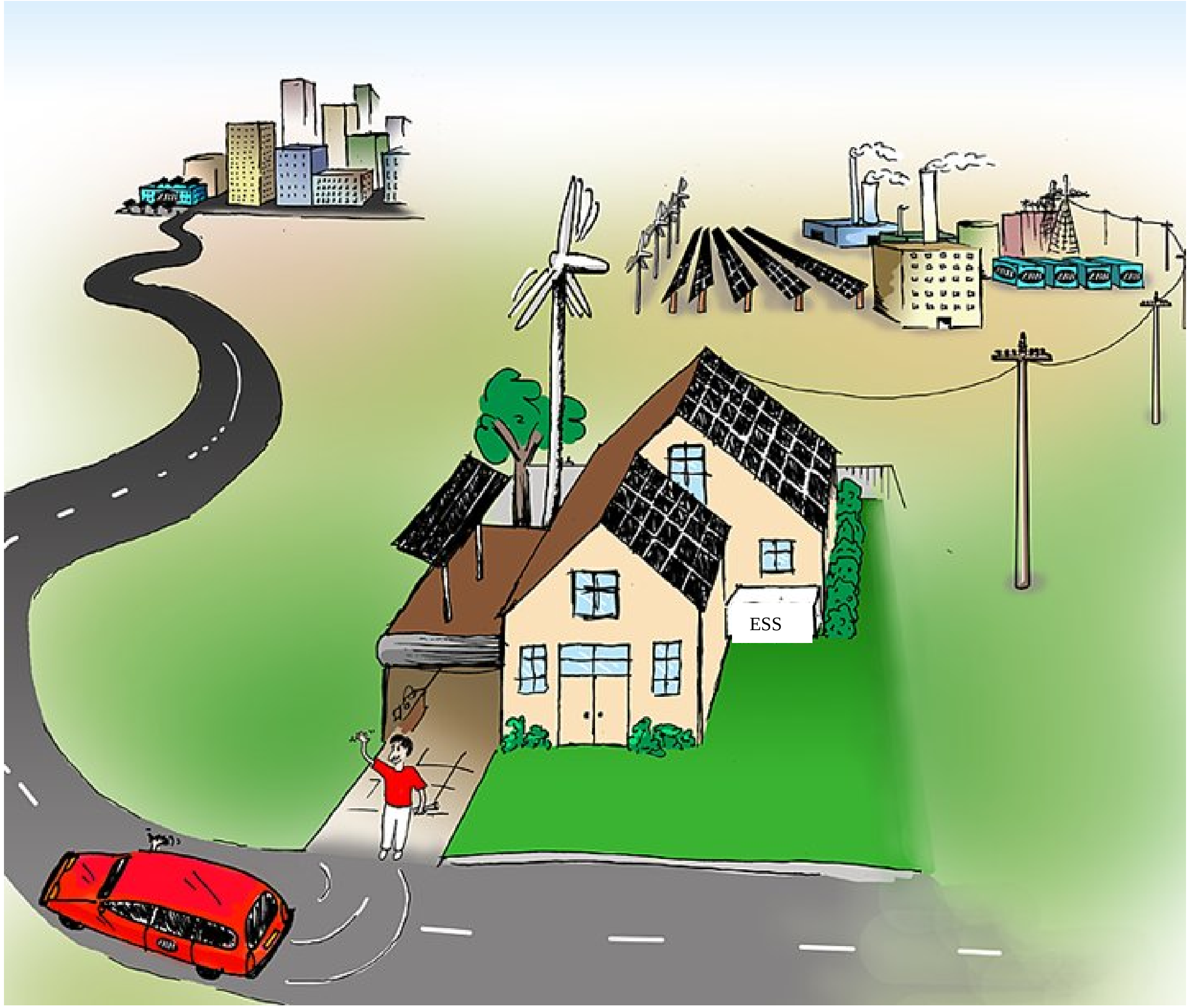
POLITICANS

- **Set frame for a real deployment of renewables**
  - Allow different structure of the networks
- **Help energy storage for allowing large RE penetration**
  - Networks operators do not allow injection from batteries
  - The storage system must be “controllable” in order to make full use of its benefits
  - Storage must be recognised as a “distributed energy resource”: easier grid-connection
- **Set legal frame for a honest attribution of benefits of storage**
  - Unbundled networks hinder storage from being profitable
- **Fund research on storage and alternatives**

- **Technological development is of interest**

- **Research on storage integration presents very large potential**
  - Data is needed for feeding multi-criteria analysis
  - Define function, location and size of storage
  - Make cost comparision including external costs
  - Always watch efficiency of the whole chain
  - Calculation of the value of services of storage

- **Alternatives are**
  - Shifting of load curve: washing with the sun!
  - Dropping of excess power => feed the hydrogen economy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