NiCd

$$2\ NiOOH + Cd + 2\ H_2O \Leftrightarrow 2\ Ni(0H)_2 + Cd(0H)_2$$

Advantages	Disadvantages
- High capacity, fast charging - Low temperature compatibility - High # of cycles (1000- 4000) - Capacity widely independent from discharge current - Low dischargeable	- High temperature sensitive (> 45 °C) - Memory effect - Environment, Cd, Cd(0H)2 is toxic - Highly self discharging - High price (3-5 x more than lead acid) - Bad efficiency (in full cycle use)

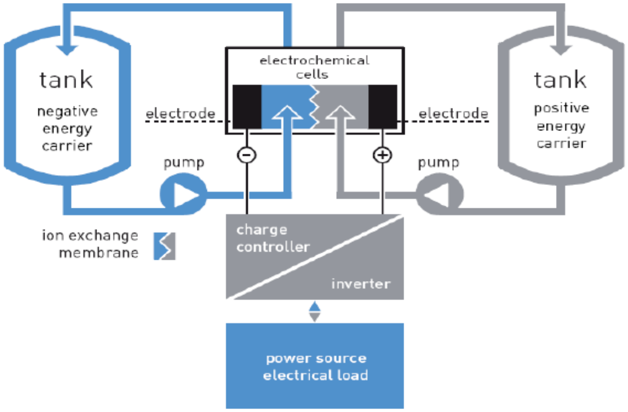
NiMH

$$NiOOH + MeH \Leftrightarrow Ni(0H)_2 + Me$$

Advantages	Disadvantages
- High energy density - Fast chargeable - Ecological - Low costs - High lifespan	- Low power denity - Memory effect (compare NiCd) - High self discharging - Low temperature - Similar price as NiCd - Worse than Li-Ions (energy density)

CellCube, Redox Flow (BALSWISS/Gildemeister)

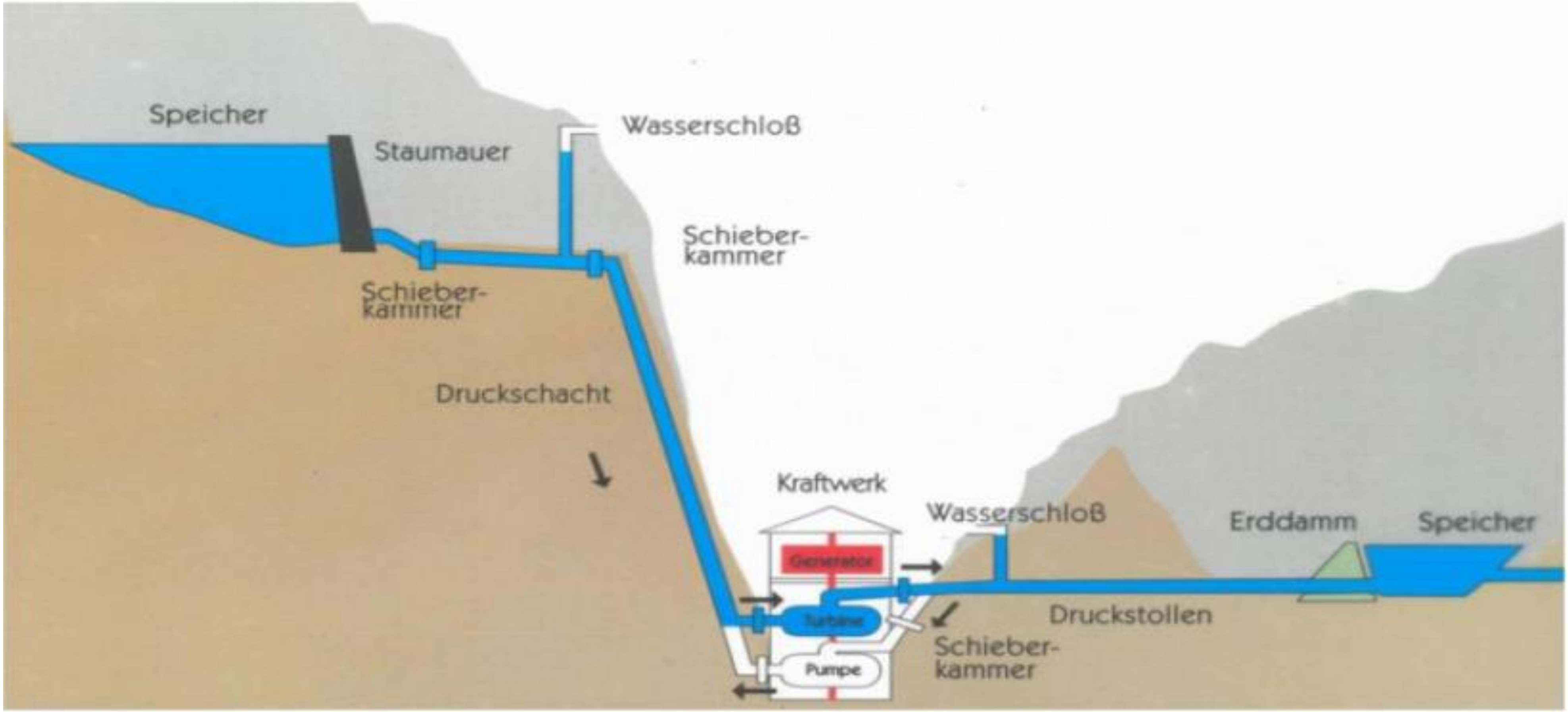
Power and Energy*		
AC max charge power	200 kW	
AC max. discharge power	200 kW	
Energy capacity nominal	400 kWh (useful energy depends on app)	
Battery and System Voltage		
Output Voltage	400 Vac	
Monitoring		
Status collection via remote request email	SOC, avail Energy, Charge/Discharge power	
Roundtrip efficiency		
Charge/Discharge cycle	up to 70%	
Multi Stage Operation	reduces self-discharge losses at small load power request	
Discharge times at nominal power rating **	**kW DC-Battery power**	**kW AC-Inverter power**
1 h	220	200
2 h	140	130
3.5 h	110	100
5 h	80	70
Self discharge		
self discharge at Cold Standby **	< 100 W	
self discharge at tank	negligible (< 1% per year)	
Size and weight		
Dimensions L x W x H	6.000 x 2438 x 5792 mm	
empty weight (w/o fluid)	20,000 kg	
Gross weight (w/ fluid)	55,000 kg	
climatic environmental conditions		
Operational temperature inside the battry remains between 20°C (68F) and 35°C (95F)		
Suitable Insulation (for heating or cooling) allows deployment in all climate zones		



→ ~ 20 Wh/kg,

but weight not important for stationary use!!

PSW: Pump-Storage Hydro-Power



Reference: Axpo Holding AG

- Pump, turbine or combined machines
- 70-80% efficiency, depending on power and pressure (water level)

Comparison of Energy Storages

HOCHSCHULE LUZERN

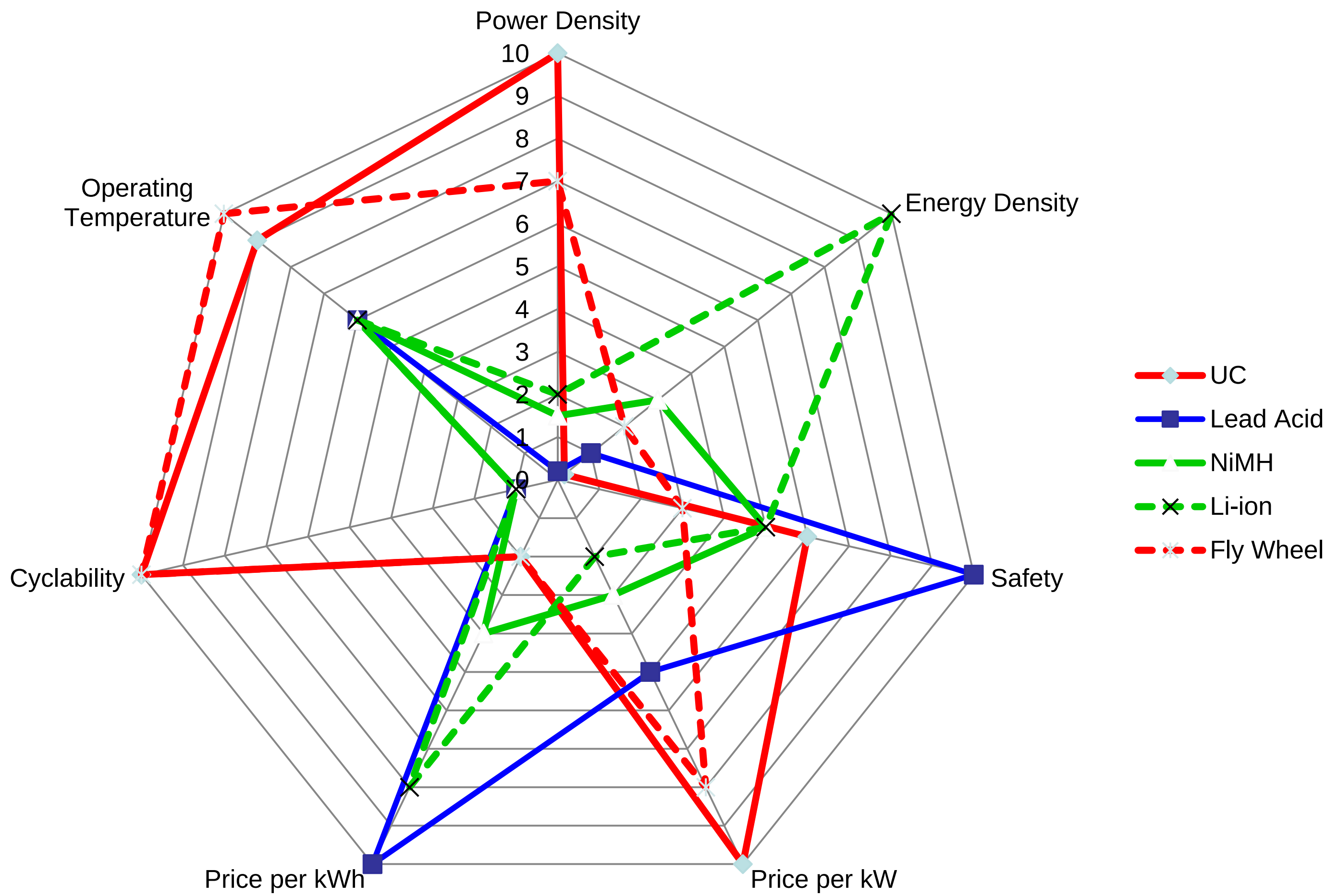
Technik & Architektur

	Batteries	EDLC (SCAP)	Conv. Capacitors
Time of Charge	1…5 h	0.3…30 sec	10^{-3} … 10^{-6} sec
Time of Discharge	0.3 … 20 h	0.3 … 30 sec	10^{-3} … 10^{-6} sec
Spec. Energy (Wh/kg)	10 … 140	1 … 10	< 0.1
Spec. Power (W/kg)	< 1000…2000	< 10000	< 100000
Lifetime (C/D cycles)	< 1500	> 500000	> 500 000
Efficiency	0.7 … 0.90	0.85 … 0.98	> 0.95

Storage:	SCAP Maxwell	Blei Optima	NiCd	NaNiCl	Ni/MH	NaS	Li-Ionen LiCoO	Li-Ionen LiFePO
Energy density [Wh/kg]	**5.5**	31	50	110	80	107	140	80
Power density [W/kg]	**<20'000**	* 412	100	150	175	15	400	>1000
max. discharge rate	**>>>**	10-15C	10C	gut	2C	C/8	5C	15C
no. of cycles Zyklenzahl (durabil	**1'000'000**	250	1000	1000	1000	2500	800	2000
Self discharge [% each month]	**barely**	barely	15	barely **)	15	barely **)	4	4
Price indication each Wh in [Fr.]	**15….25**	0.25	0.6	0.7	0.5	0.6	0.5 …. 4	

Reference: V.Härri, 2010

Comparison Storages



J. Grbović, ENERGYCON 2012, Florence 9-12 September 2012

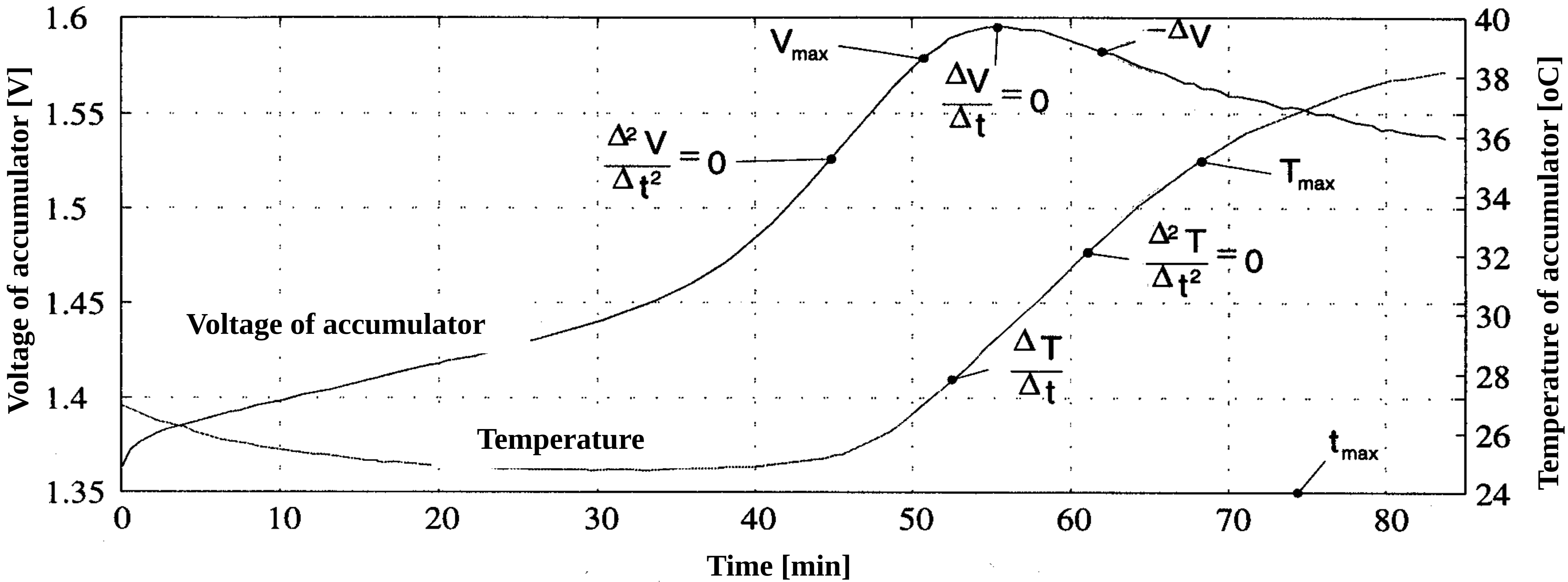
General Classification

- electrical – others (H_2, compressed air, thermical)
- Size: power and energy @ cycles, parameters
- Small – hudge (spring of ball point pen – pump storage plant)
- Use: mobile, stationary, balancing, @ better time
- Place: mobile, in house decentral, region, town, central,
- Integration standard: boardbatterie – ZEBRA – Redox-Flow
- economics

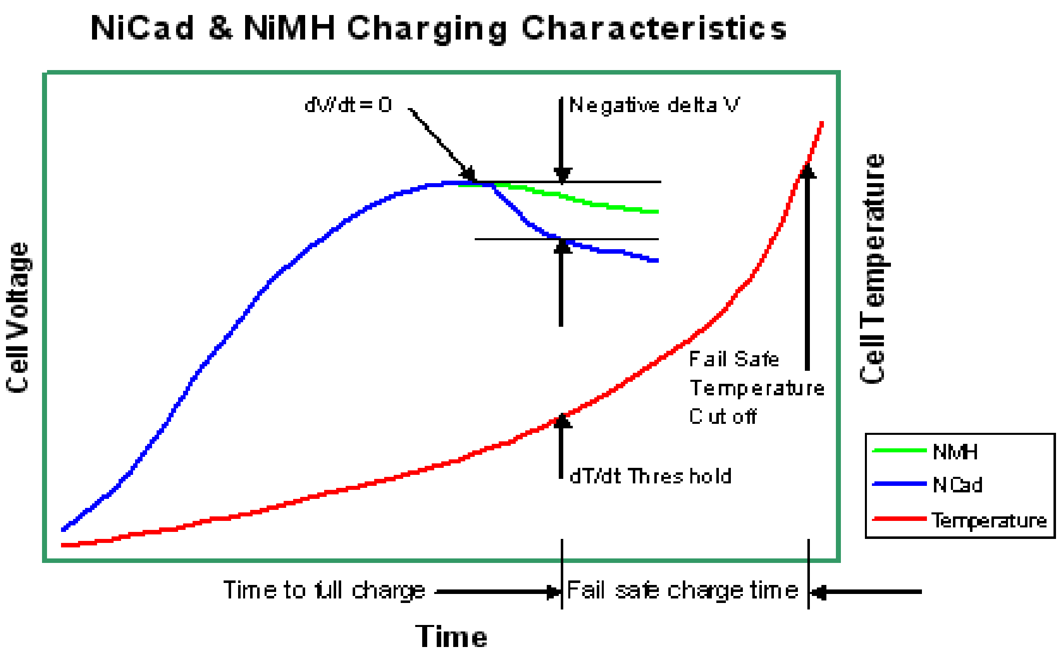
Definitions

- Batteries
- Accumulators: rechargable batteries
- Supercapacitors, ultracapacitors, EDLC (el. double layer capacitor), Helmholz, typ. 2.5V: electrical high capacitcapacitors
- Primary cells: energy through unique chemical transformation! Nin reversible process
- Secundary cells: electric rechargable cells; electricity is a secundary type of energy by reversible process!
- SoC, DoD: State of Charge, depth of discharge in %
- C: unit of discharge current. 1C is a charging current equal to the number of charges of the sorage in [Ah]. 3C : charged in 20min., C/5 charged in 5h.
- CV, CC : charging profiles, means constant voltage, constant current respectively
- Full cycles, shallow cycles → important for life time
- Thermal Runaway: positive thermical feedback loop (warming up / explosion)
- Charging profiles: done by components, Ics or CCS Computer Charging System: model calculation on a chip

Charging principles



Charging Profile 1 NiCd, NiMH



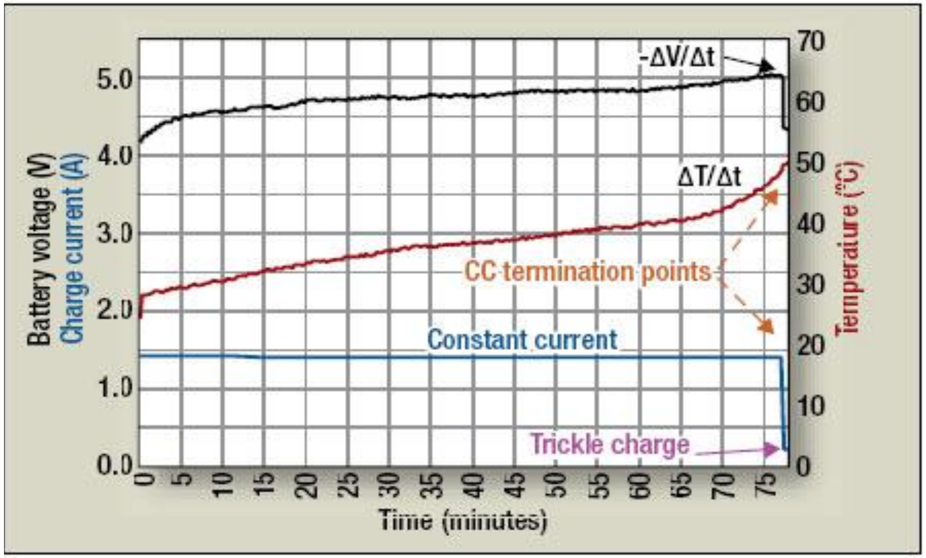
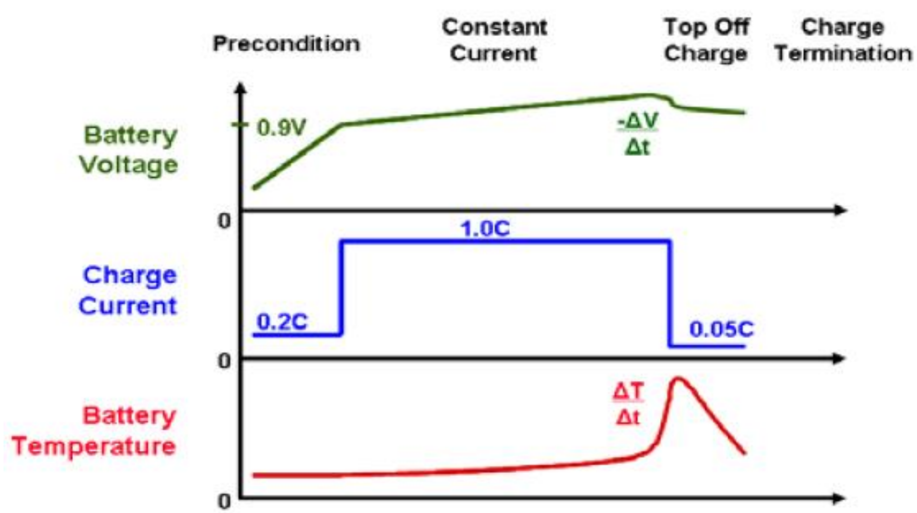
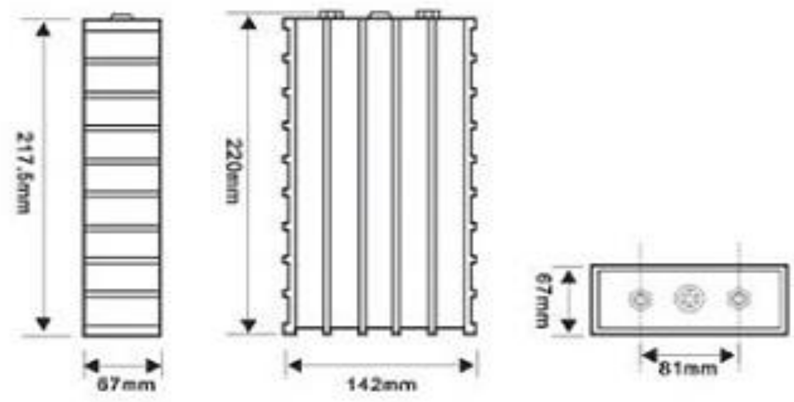


Fig. 2. *A NiMH or NiCd battery-charge profile for a three-cell battery-pack charging employs a constant 1.35-A charge current.*

Figures:
above left: principle diagram
below: showing additally the current, including precharge
right: practical graphs



Battery-Facts:
State of the Art? CALB LiIonen LiFePo4



→ ~ **100 Wh/kg**

Parameter	Wert
Ladungsinhalt, Spannung	100Ah / 3.6V
Entladestrom, Ladestrom	4C, 3C
Zyklen, 0.3C,80% DoD	2000
Masse, Grösse (cm)	3.2kg, 14.2 x 67 x 220

Examples: Integration by Lucerne (CC IIEE), LiFePo

1st: Profiles are Important for the Design

A: Load profile: profile for one single charging and discharging cycle of the energy-storage

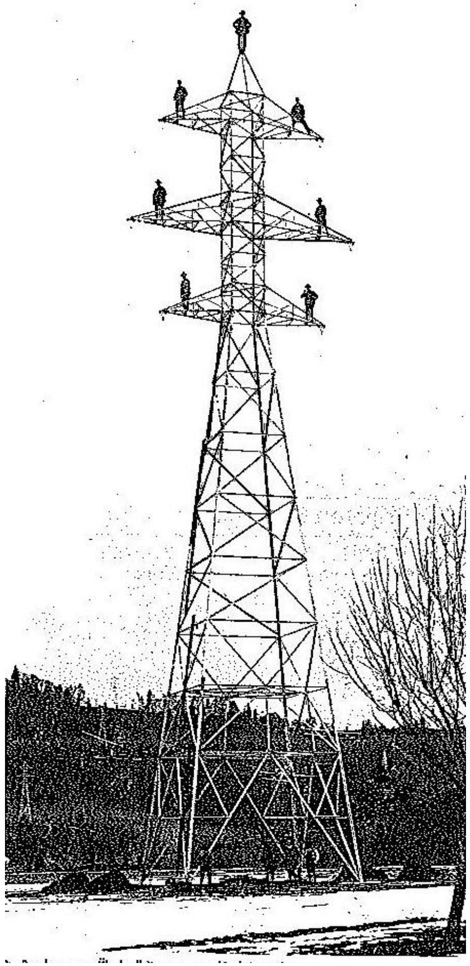
B: Operational profile: Numbers of cycles over the lifetime?

Designing Batteries (Design-Flow)

Step 1	Select the module rated voltage	DC-Link Voltage? Is there any DC/DC converter?
Step 2	Select module capacity for given energy capability and efficiency	1.Energy? 2.The power may cause reduction of cycles → therefore it may be necessary to oversize the capacity (shallow cycles)
Step 3	Load- and operational profile for determination of life-time and cycles? Mobile or stationary? → Fixing the technology (costs ?)	Load profile: concerning 1 simple charge- and discharge cycle! Operating profile: cycles over the lifetime
Step 4	Number of series connected sub-cells	
Step 5	Capacity of single cell? Parallel modules?	Take in account that modules can be connected in serial line or in parallel!
Step 6	Thermal design according to profiles above.	Simulation may be necessary if profile is complicated!
Step 7	Integration aspects, voltage balan-cing, security, filtering, BMS control, communication, weight, packaging	→ To be solved
!!!	For all steps:	→ Iteration may be necessary

Repetiton: Infrastructure!

- Renewables are important, but…
- Even more important are
  - HV-Grid and distribution grid
  - Energy storage!
- Rather laying in the ground?
- DESERTEC ??
- Or completely different:
  only decentralized power supply??



1st Findings: So Many New Concepts

storages

Smart-Grid

Fast-Charging

Infrastructure

Well to Tank

ISO

G2V

Load-Leveling

Decentralized Power Supply

Renewables

V2G

PV

Smart-Metering

Ancilliary Services

Emobility

Feed-In-Incentive

Transmission lines

Tariffs

Building-Automation

Definitions and Examples

Smart-Grid=

Smart grid is a type of electrical grid which attempts to predict and intelligently respond to the behavior and actions of all electric power users connected to it - suppliers, consumers and those that do both – in order to efficiently deliver reliable, economic, and sustainable electricity services. (Wiki)

e.g. Enel, 2005.

e.g. US, the city of Austin, since 2003,

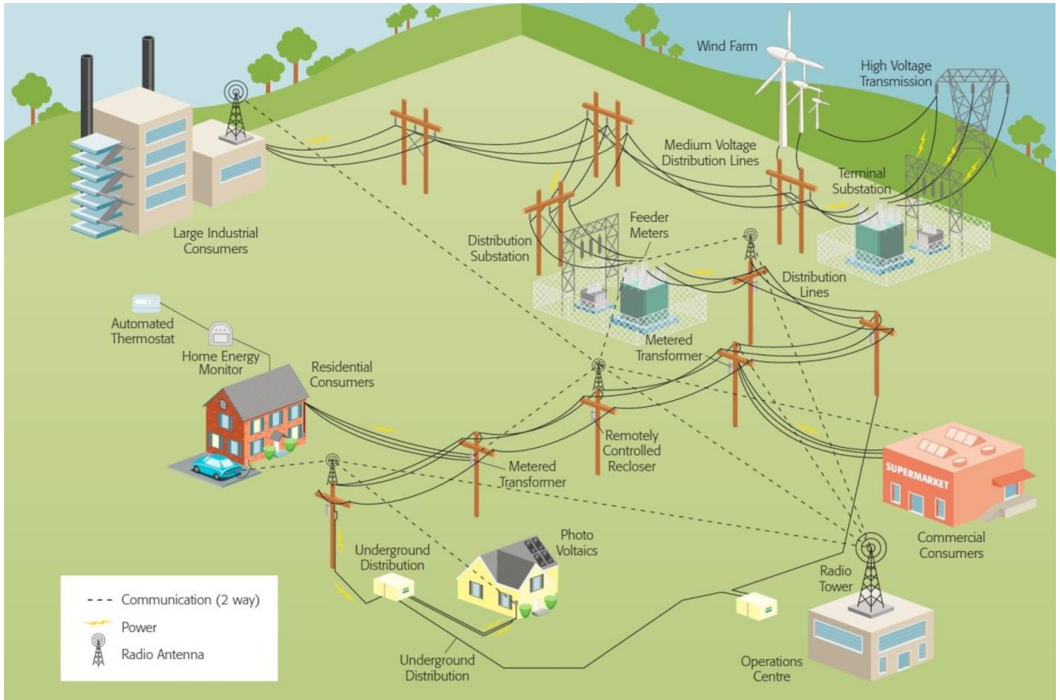
e.g. Boulder, Colorado 2008.

e.g. Hydro One, in Ontario, Canada 2010, 1.3 million customers

e.g. The City of Mannheim in Germany is using realtime Broadband Powerline (BPL) communications in its Model City Mannheim "MoMa"

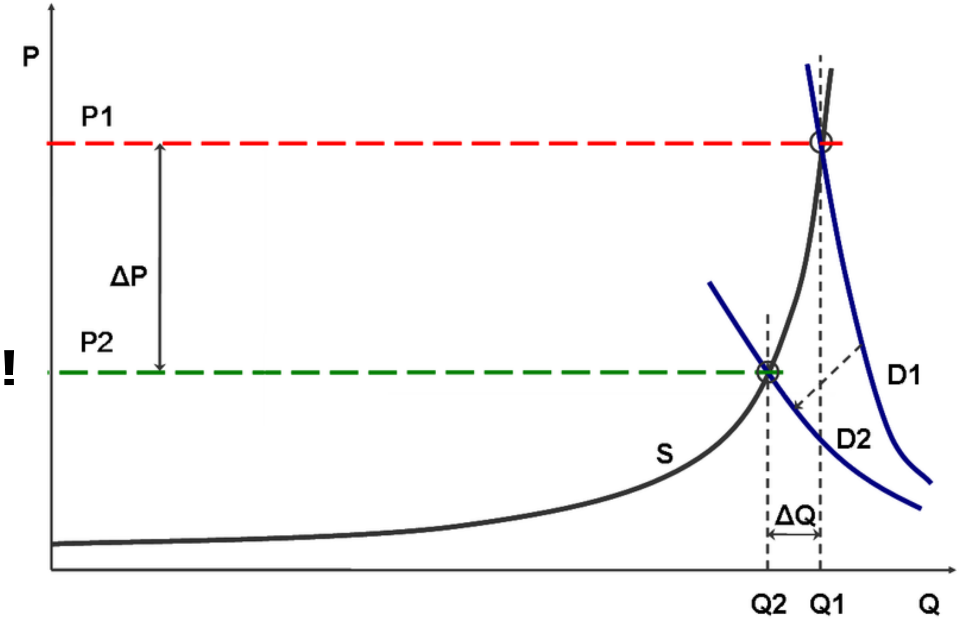
Understanding Smart-Grid 2:

Smart-Grid (II)-the ideas: what are the differences between the 2 pi



DR Demand-Response, Electricity Pricing

→ So widely used diagram!



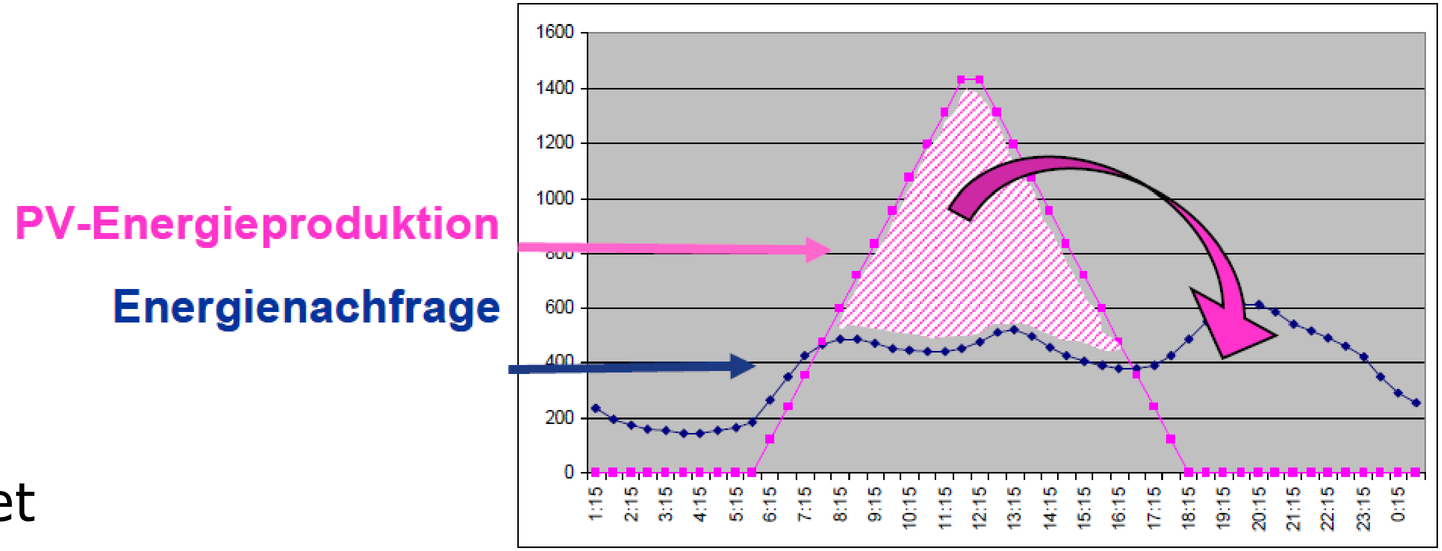
Explanation of demand response effects on a quantity (Q) - price (P) graph with the curve S for the supply side. Under inelastic demand (D1: high demand of needed power) extremely high price (P1) may result on a strained electricity market. If demand response measures are employed the demand becomes more elastic (D2: less demand for delta Q, e.g. storages). A much lower price will result in the market (P2).

It is estimated that a 5% lowering of demand would result in a 50% price reduction during the peak hours of the California electricity crisis in 2000/2001.

Wikipedia, 2012

The market also becomes more resilient to intentional withdrawal of

When batteries do make sense for PV-plants?? (2)



- Peak Shaving
- Energy market
- Best tariffs, but only for about 1 day ??
- Less costs for better infrastructure

- → But interests of stakeholders?

Quelle: SAFT Batterien

Peak Shifting generally and with Storages: Reduction of P_{max} by Comprehensive Survey

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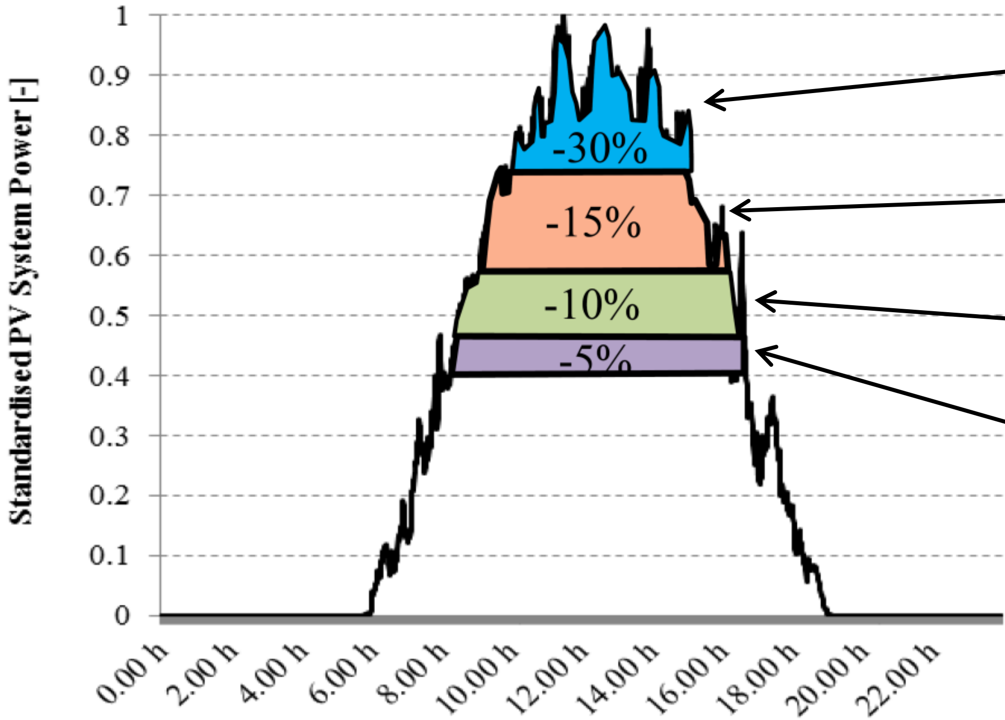
Technik & Architektur

Consider hole system: PV, storage, consumption, EV, user (visualization), communication to DSO, surrounding , architecture



PV-converter: 70% Pnom

Losses?

Smart charging stationary storage

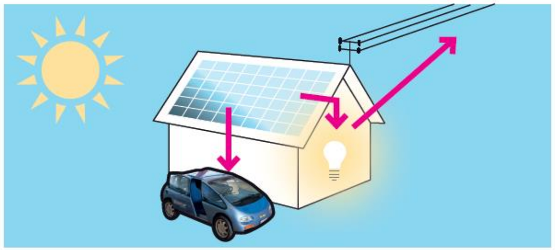
HEMS (water heater)

East-west facing PV-panels

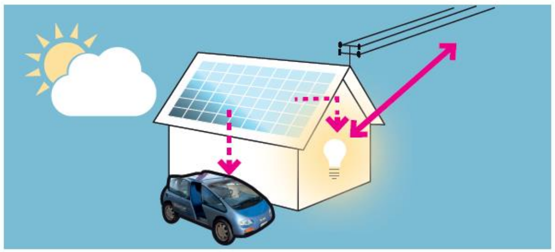
→ Less problems with DG in the grid!

Referece: CC IIEE, CH-Horw

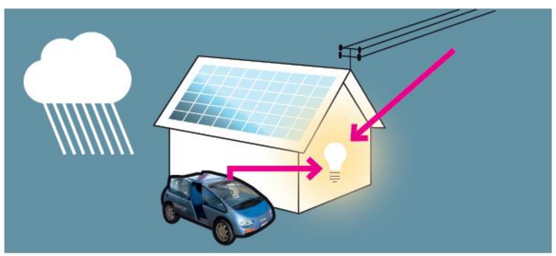
Idea of V2G



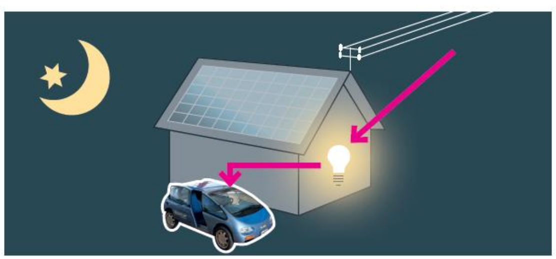
sunny day:
- **PV charges Blue-Angel**
- **PV powers electrical appliances of building**
- **PV feeds back to grid**



cloudy day:
- **PV charges Blue Angel intermittent**
- **PV powers electrical appliances intermittent**
- **PV feeds back to grid when possible**
- **grid feeds when needed**



rainy day:
- **no PV energy**
- **V2G: Blue Angel provides power to building to reduce peak loads on the grid**



at night:
- **no PV energy**