EERA Smart Grids R&D Workshop

c/o RSE – Via Rubattino 54, 20134 Milano

SP 4: Electrical Storage Technologies

Storage Economics

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Task 4.5 Economic and technical benefits of incorporating an ESS onto network

Task will start during this year and finished month 36

Three Sub-tasks:

1. Algorithm impacts on storage lifetime expectancy
2. Economic feasibility study of choosen concepts
3. Environmental influences

Participants:

SINTEF (Task leader), VTT, JRC, ERSE and ENEA

Examples of interesting R&D activity outcomes are:

1. Impact on life time ecpextancy of assets
2. Economic feasibility in terms payback time of chosen concept
3. Impact on energy bills
4. Number of renewable generation connections possible with/without storage

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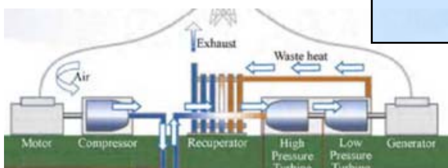
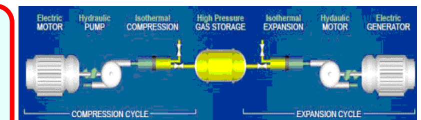
Smart Grids Applications – Energy Storage Technology

Mechanical
- **Gravitation**: Pumped Hydro
- **Kinetics**: Flywheel

Thermodynamic
- **Pressure**: Compressed air (CAES)
- **Heat**: Thermoelectric
- **Pressure & heat**: ACAES, ICAES





Electrochemical
- **Batteries**: Lead acid, Lead carbon, NiCd, NiMH, NaS, NaNiCl, Na-ion, Li-ion, Metal air
- **Flow cells**: Vandium, ZnBr, FeCr
- **Hydrogen**: Electrolyser & Fuell cell

Electromagnetic
- **Electric**: Capacitors, Supercapacitors
- **Magnetic**: Superconducting (SMES)

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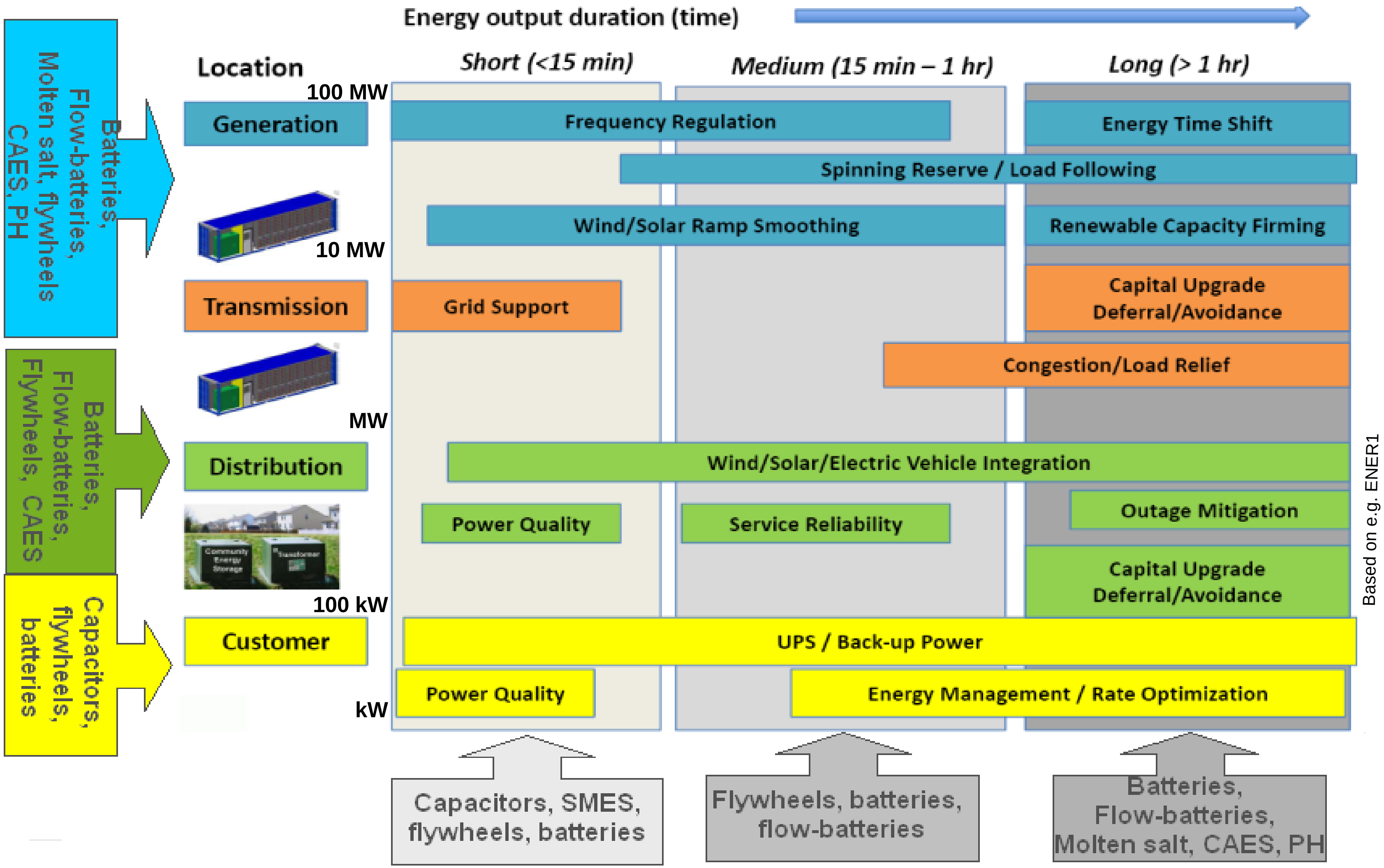
ES in European Smart Grid Applications

Different types of ES cover the needs of the SG application services



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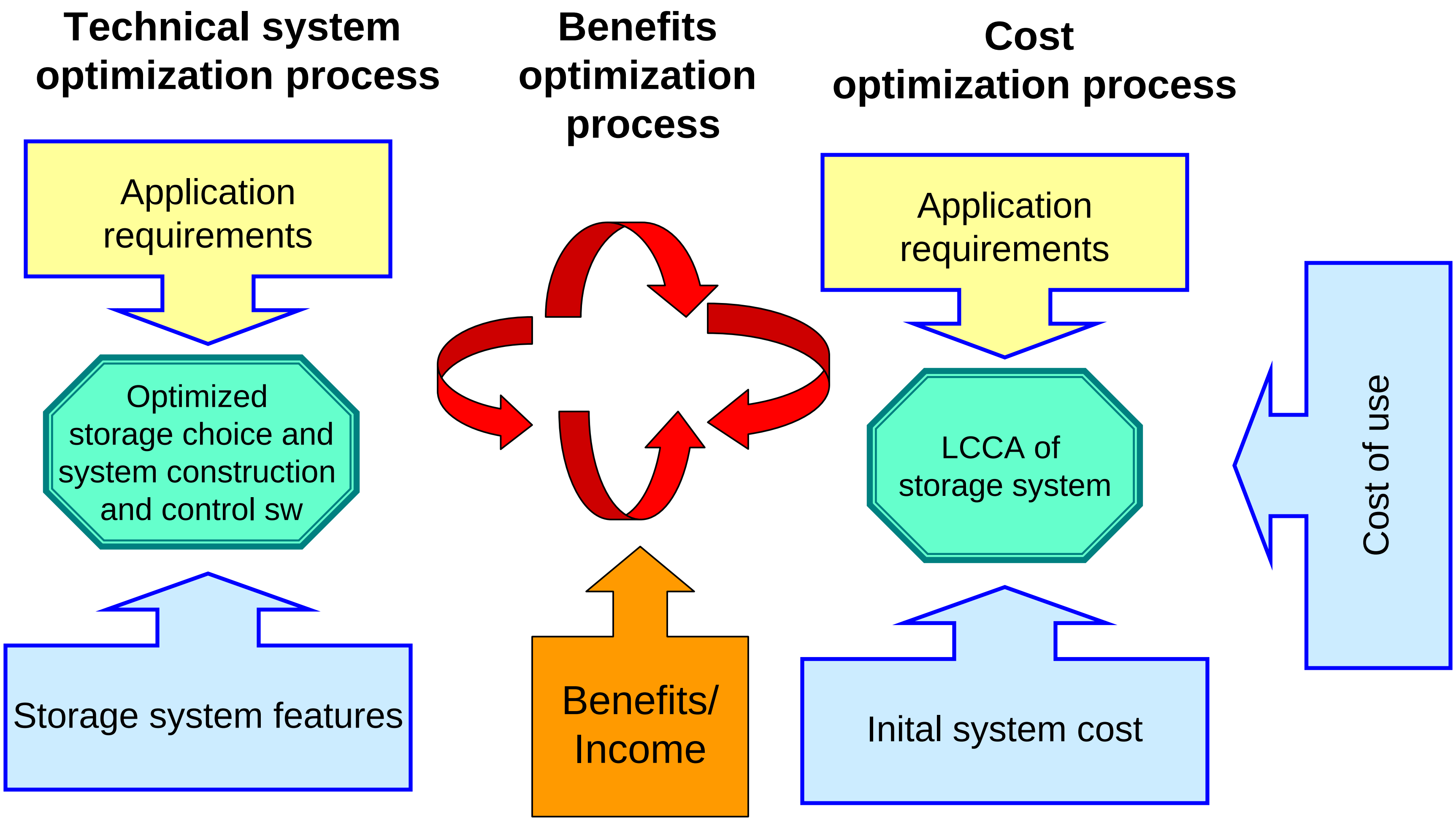
Energy storage system design is a multilevel and multistage optimisation process



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Energy storage system design is a multilevel and multistage optimisation process

Application/system requirements

- amount of cycles per time
- lifetime
- start up time
- response time
- round trip efficiency
- power capacity
- energy capacity
- size limits
- weight limits
- location limits
- grid connection limits & requirements
- safety requirements
- environmental requirements
- maintenance requirements
- profit requirements

Economics

- ES cost /kW
- ES cost /kWh
- Control system cost
- Grid connection cost
- Power electronics cost
- System construction cost
- System design cost /kW
- Renovation cost /y
- Maintenance cost /y
- Recycling cost

ES technical features

- cyclic lifetime
- physical lifetime
- response time
- start up time
- round trip efficiency
- power capacity
- energy capacity
- self-discharge, capacity drop
- cell voltage
- charging limits (time, current, voltage, temperature, special functions)
- discharging limits (DOD% etc.)
- balancing needs
- power electronics
- safety systems
- grid connections
- basement and buildings
- environmental requirements
- maintenance requirements

Optimized ES type, structure and control

- Cost of selling power
- Cost of purchasing power
- Cost of using power

- Income /kWh
- Other benefits

net present value (NPV),
internal rate of return (IRR),
modified internal rate of return (MIRR),
profitability index (PI),
payback time.

Optimized cost–benefits ratio!

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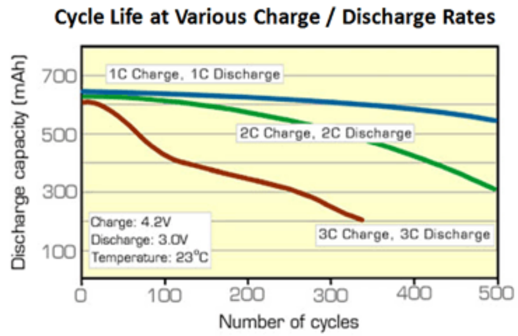
ES Economics – Influential factors – Charge-discharge regime

Charge-discharge regime can have a significant influence on ES economics having effects on

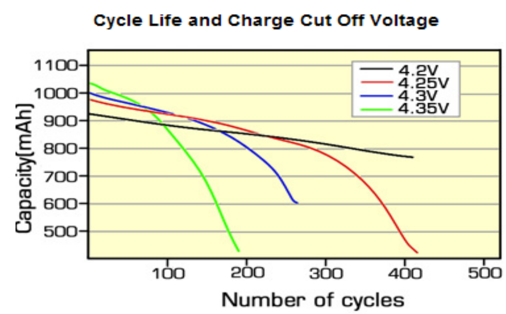
A. Energy Storage physical lifetime
   1) High current (or voltage) – aging effect (in use and storing)
      -Redusing charge cut-off voltage increase Li-ion battery cycle life
   2) High temperature – aging effect (in storing and use)
   3) Partial discharge cycles – increase lifetime (Not with NiCd)
      -Charging to less than 100% capacity and avoiding deep discharge (protection circuit) increases battery life (Li-ion)

C. Energy capacity
   1) Balancing functions ensure full capacity compensating differences between batteries (e.g. Li-ion battery)
   2) Equalixation functions overcharge slightly charged cells charging fully the undercharged cells (e.g. LA batteries)
   3) Reducing float voltage – reduce capacity but increase cycle life

D. Charge cost vs. charge current
   1) High current – fast charge => higher basic electricity connection cost
   2) High current at peak price time => higher energy cost



Source: Choi & Lim - Journal of Power Sources,September 2002



Source: Choi & Lim - Journal of Power Sources,September 2002

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ES Economics – Influential factors – Cycle life

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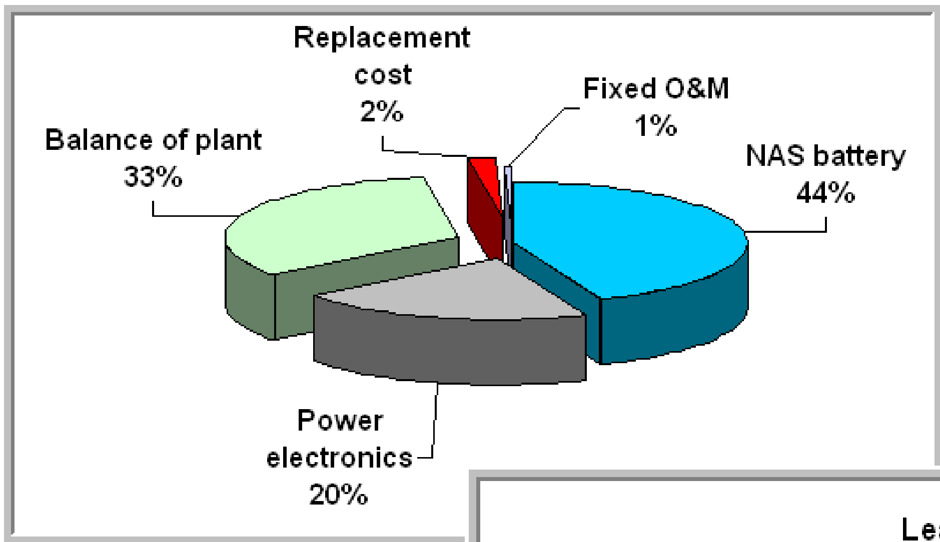
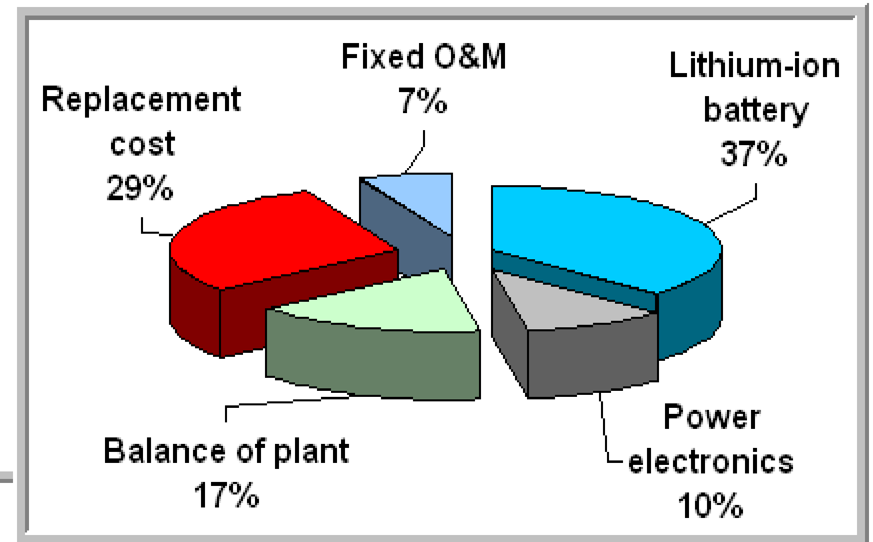
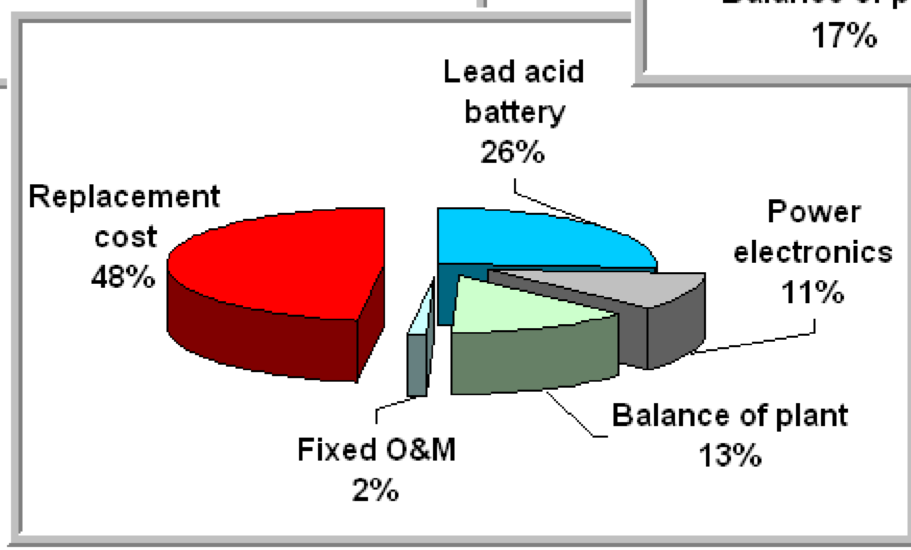
Low cycle life increases replacement cost in the applications of high cyclability and increase also environmental impacts







25 years, 100 cycles/y.

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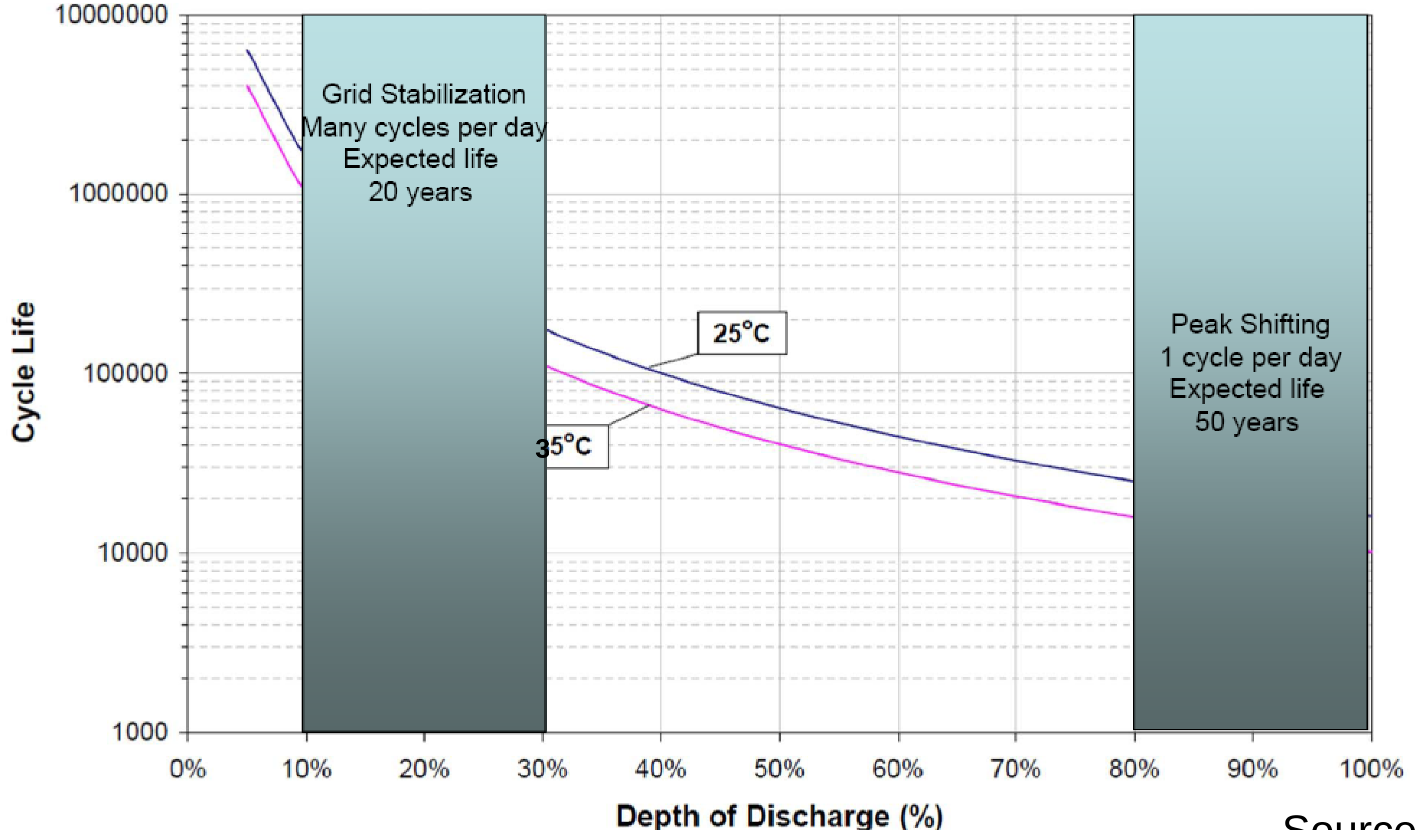
ES Economics – Influential factors – Cycle life – Operating Temperature

Cycle life capacity and the right operating temperature are important parameters in the design of an economic efficient energy storage system.
Long cycle life capability increases also storage usability.

Lithium Titanate Battery Cycle Life to 80% Capacity



Source: Altairnano

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Energy Storage Cost

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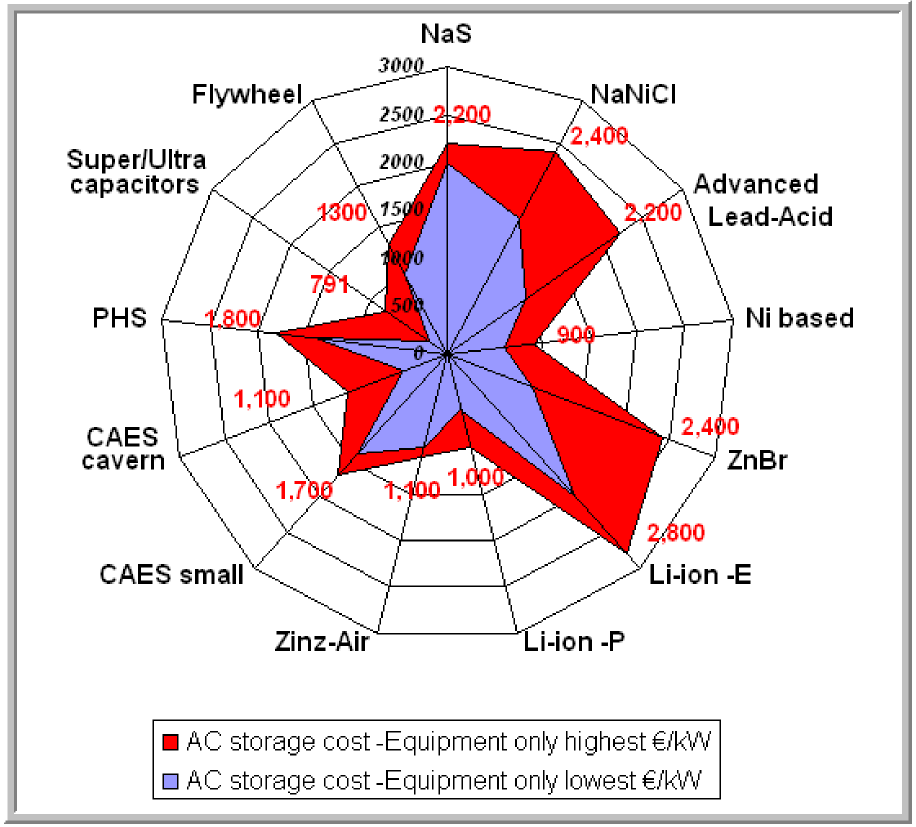
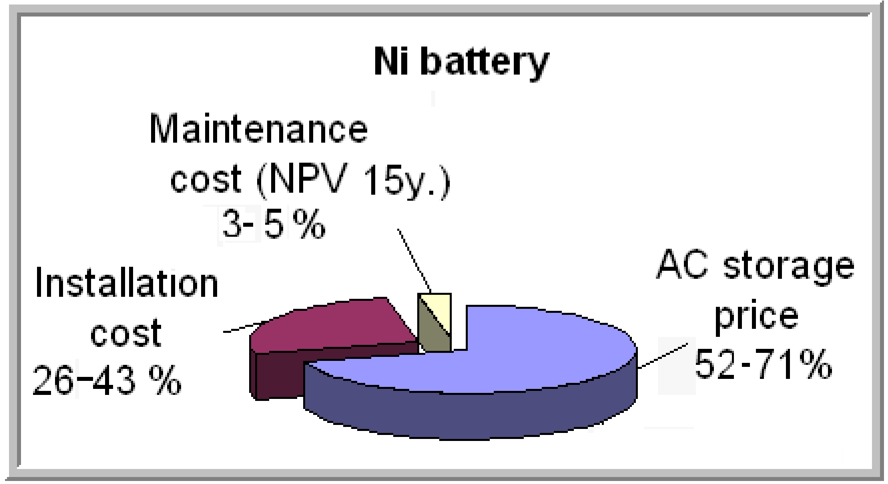
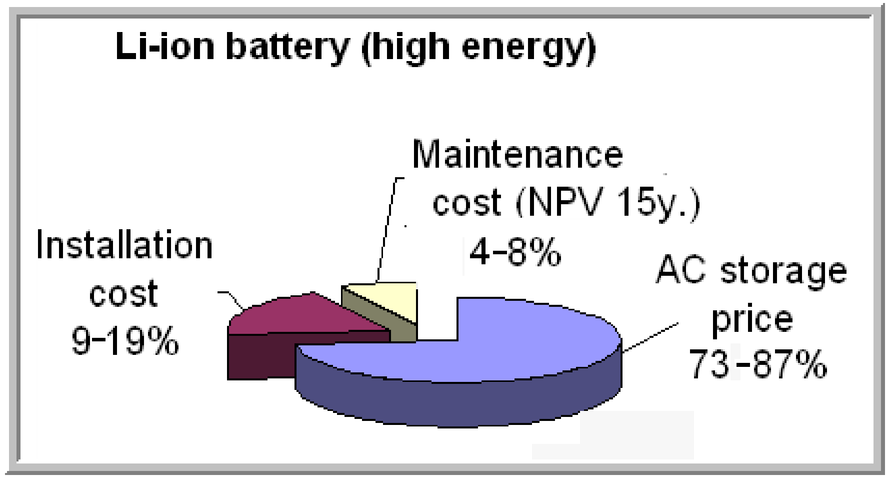


Data based mainly on Sandia/KEMA 2012





Large Differences in the Available Cost Estimations for ES!

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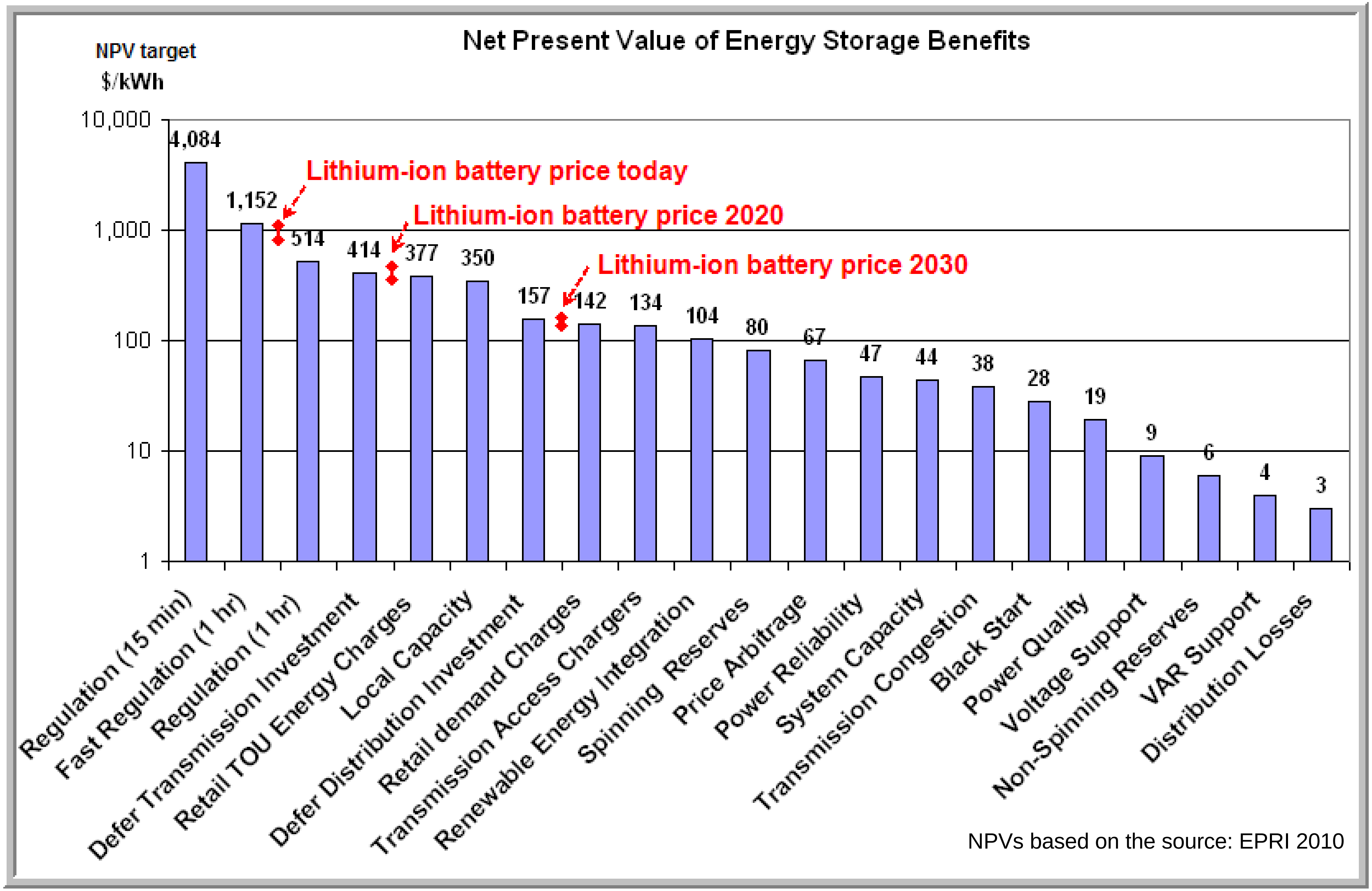
Energy Storage Benefits in Smart Grid Applications



ES in European Smart Grid Applications
Profit on electricity market with ES systems?

Today electricity storage facility could make profit in the Nordic power system

1. From buying and selling power on the spot market
2. On the regulating market, which maintain energy supply and demand balance in real time. Demand and intermittent RES supply forecasts are not perfect and the imbalances are handled by the regulating market
3. By selling ancillary services to the transmission system operator (TSO)

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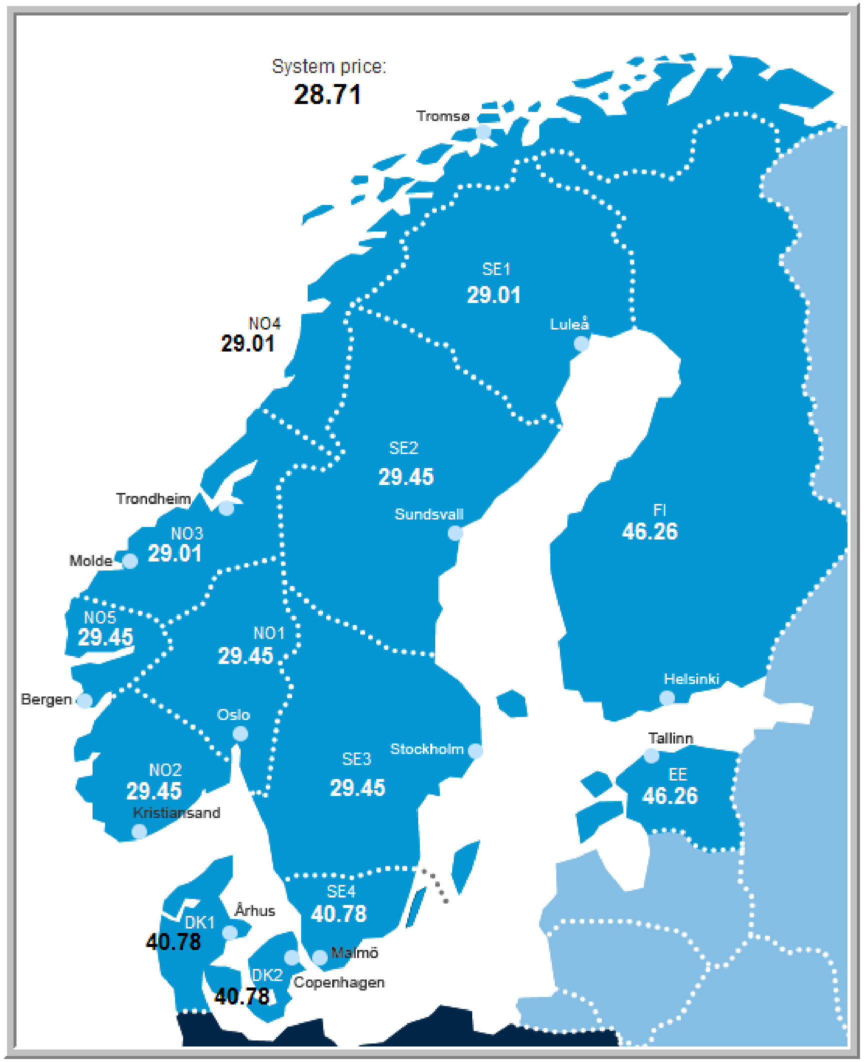
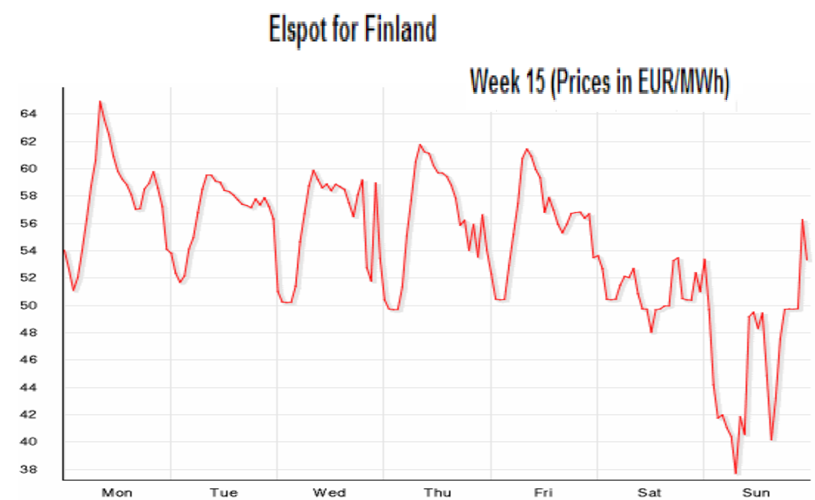
ES in European Smart Grid Applications
Profit on electricity market with ES systems?



The amount of profit will be different in different countries or even in different parts of a country because of regional pricing!

- Elspot market prices varies according to the time of a day, a weekday and seasonally



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Profit in Finnish electricity market with ES systems?

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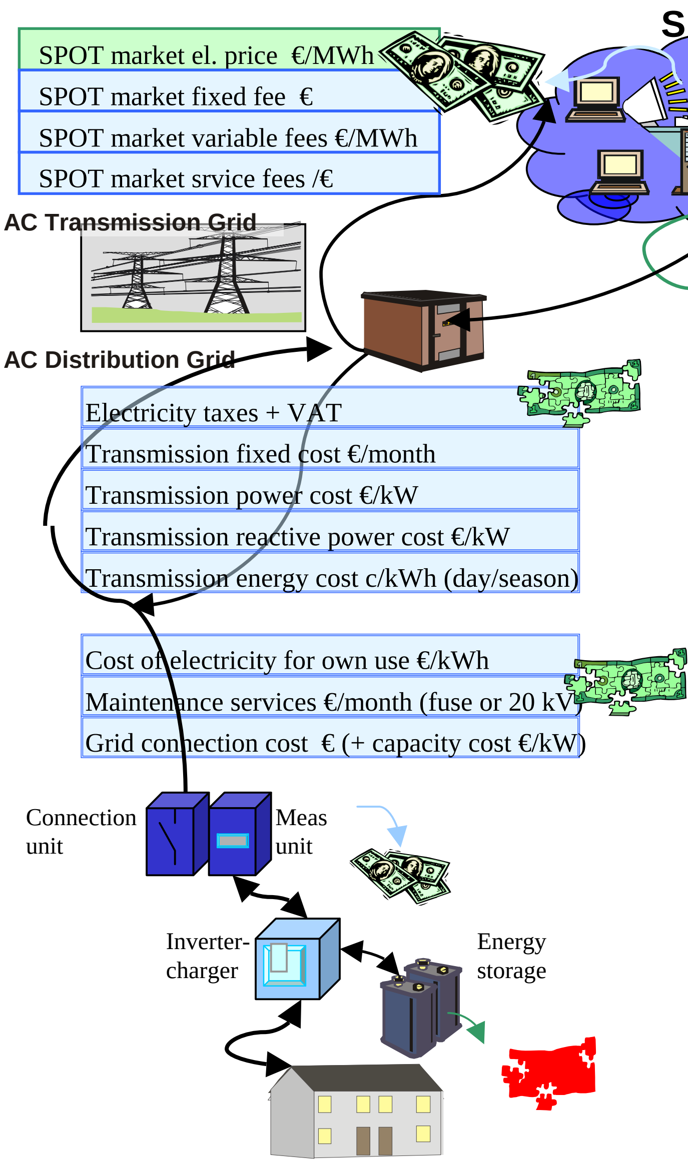
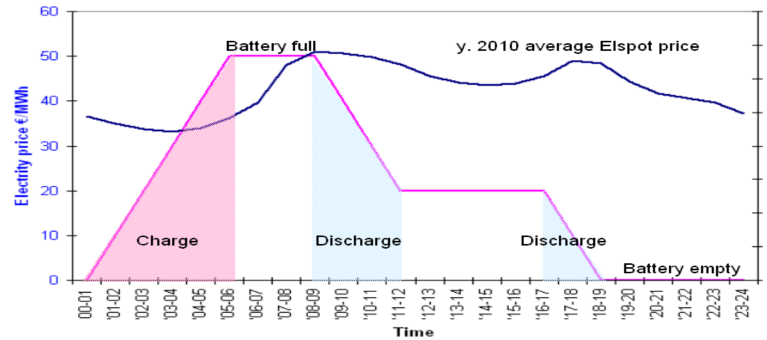
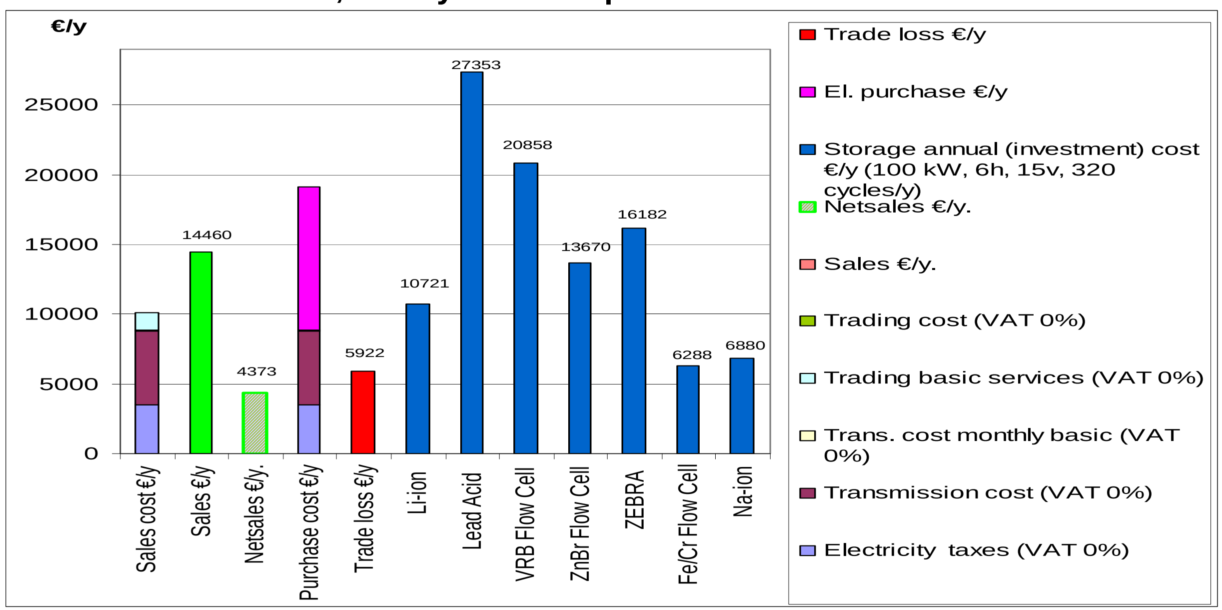


Charge during off peak hours and discharge during high price hours



100 kW, 6h/day sold and purchased



⇒For spot market trade charge/discharge price arbitrage : NOT PROFITABLE

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ES in European Smart Grid Applications
Profit on the regulating market?

Each party operating in the electricity market must take continuous care of its power balance. E.g. the balancing power market in Finland maintained by Fingrid is part of the Nordic balancing power market. A Nordic balancing bid list is drawn up of all balancing bids by placing the bids in a price order.

The price for up regulation is always higher or equal to the spot price, while the price for down regulation is always smaller or equal to the spot price. All actors can give in bids and the TSO will buy the needed regulation power according to the standard market mechanisms.

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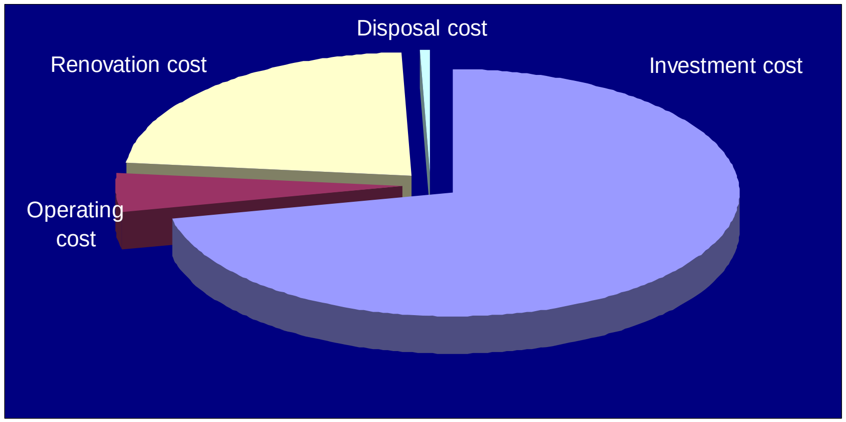
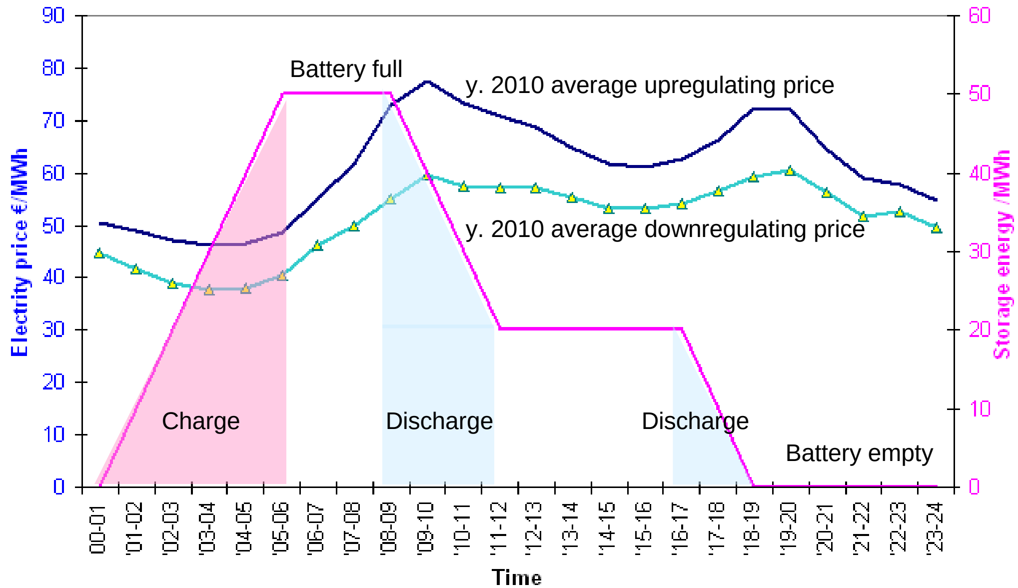
ES in European Smart Grid Applications
Profit from the balancing power market ?

Example of the fixed time based battery operation using y. 2010 balancing power market prices in price area Finland





- 10 MW, 50 MWh NaS battery system
- Approximated operation time 25 years (1 renovation after 12 years)
- Charging from 24 pm to 5 am at low price time
- Discharging am 9-12 and pm 17-19 at high price time.
- Estimated net cash flow covers 13% of the total cost (NPV)
    - ➢ No economic base for the investment

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ES in European Smart Grid Applications
Profit by selling ancillary services to the transmission system operator (TSO)?

Possible ES benefits for TSOs in ancillary services (e.g. in Finland):

- Frequency control
- Fast disturbance reserve
- Control of power oscillation to support angle stability
- Control of the changes of demand or production (in an hour)
- To decrease the need of the short period power transmission
- To delay the grid investment
- In the black-start of the reserve power
- To control the voltage level with a reactive power source

Prices for ancillary services can be regulated or fixed and monitored by regulator and determined by market or negotiated/tendered (e.g. in Finland) => difficult to estimate possible revenues => standardization needs?

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Conclusions - Future work

For more accurate cost estimations:

• Review of the cost of installed ES projects in Europe

• Evaluation all factors influencing ES life-cycle cost

For more accurate benefits estimations:

• Currently no global benefits value evalutions available for Eu

• Further work to be able to identify all possible stakeholders in different countries

• Further work to be able to identify all possible benefits for different stakeholders in the country and European level

• Further work and co-operation to be able to identify and inform of the value of possible benefits

For more accurate environmental impacts estimations:

• Evaluation of environmental impacts of different storage technologies in different applications

Overcome regulation barriers

Standardization needs for taxes, transmission costs etc.

Contribute feed-in tariffs for energy storages especially with RES?

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