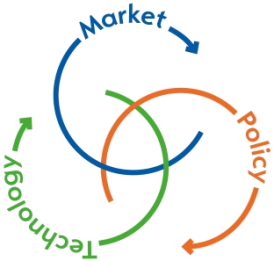

Session V – Market Driven ES – Existing Business Cases give an Insight to their Revenue Streams.

Business Cases for large Capacity Storage Projects

T. Buddenberg

Mitsubishi Hitachi Power Systems Europe GmbH

Energy Storage
Global Conference
Explaining I Exchanging I Enabling
Paris | 19th to 21st November 2014

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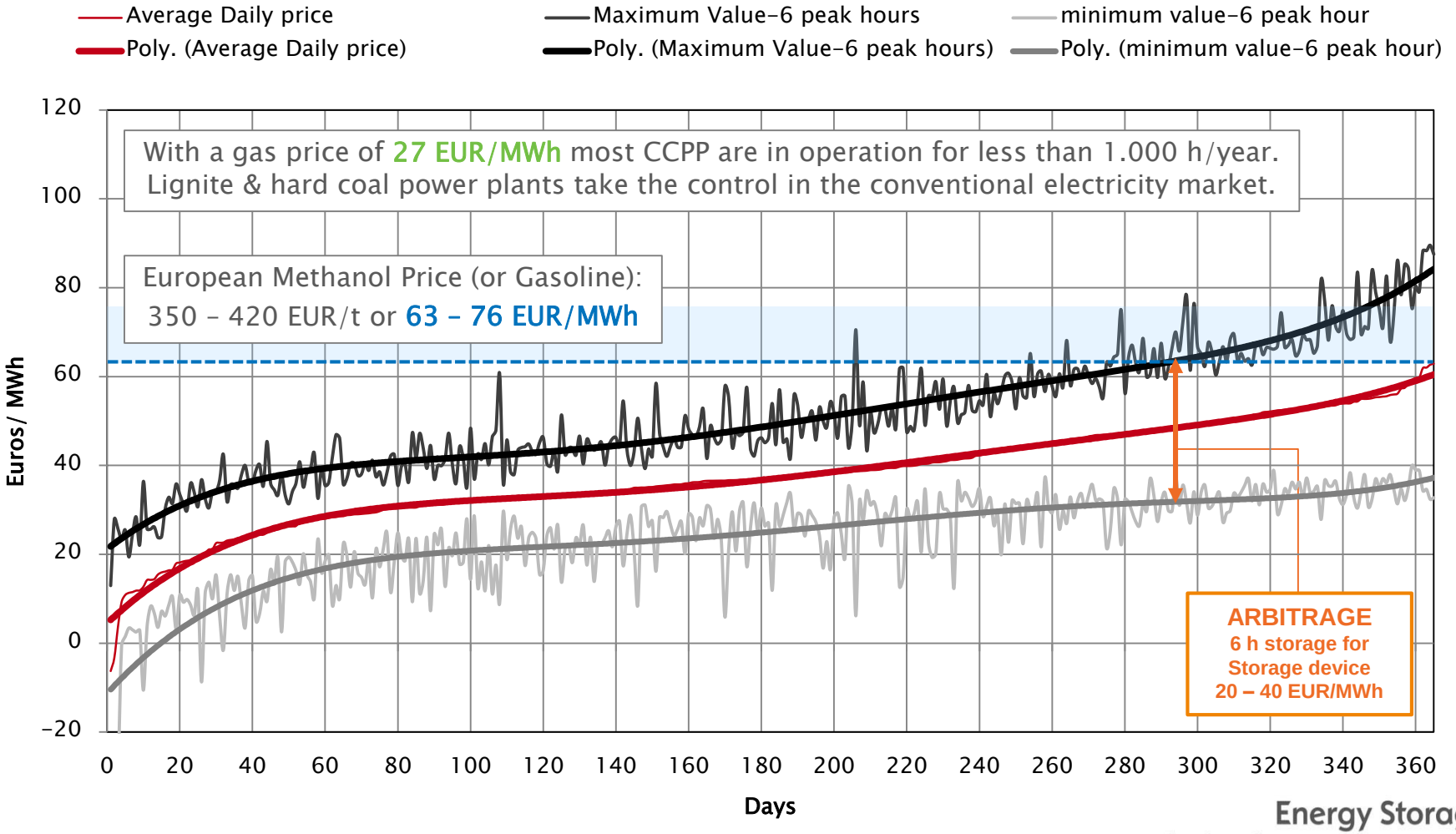
2. Future Market Development
3. ES Technologies – Overview
4. Liquid Air Energy Storage (LAES)
5. Pumped Hydro Storage (PHS)
6. Conclusions
7. Outlook towards Power to Fuel (PtF)

Introduction

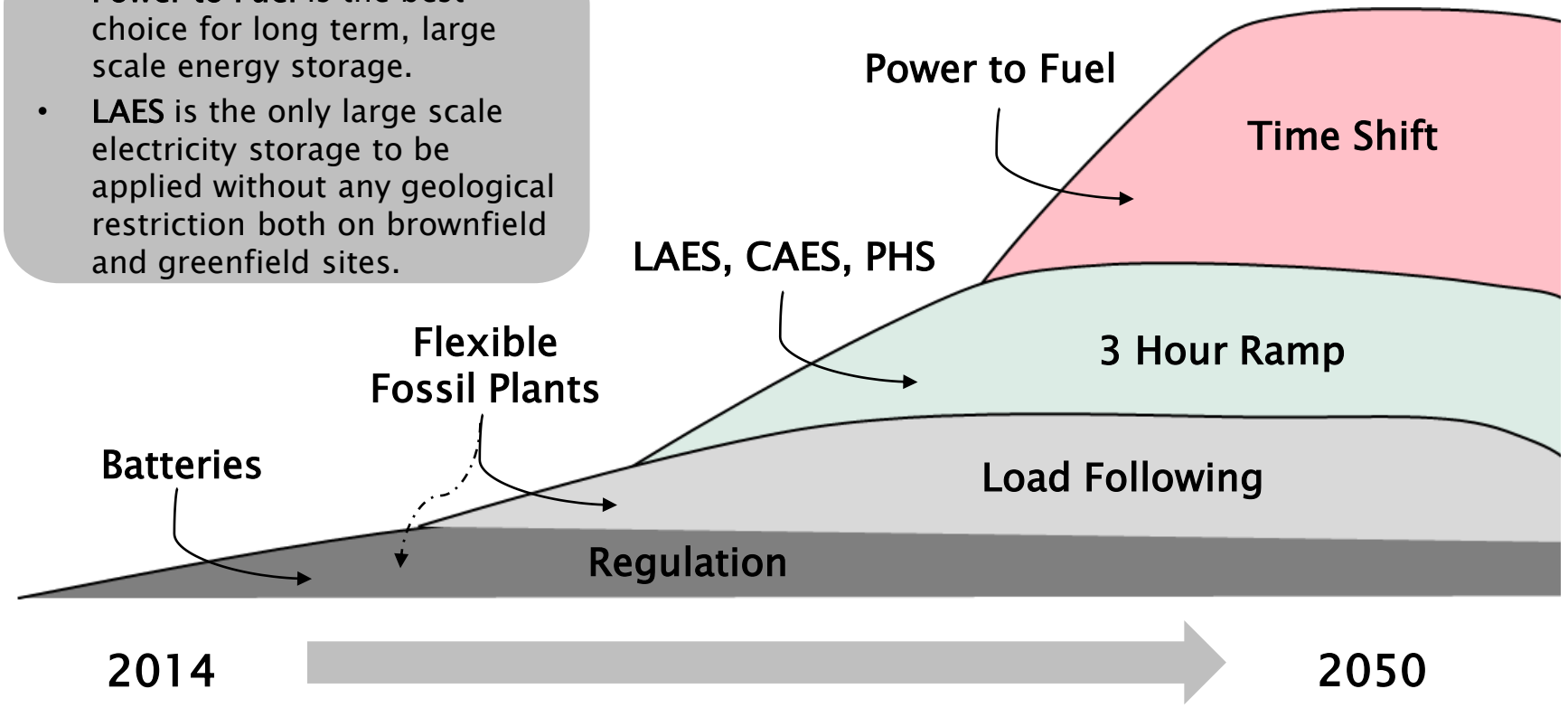
Energy Pricing in Europe – Daily Electricity Prices 2013 (PHELIX)



Future Market Development

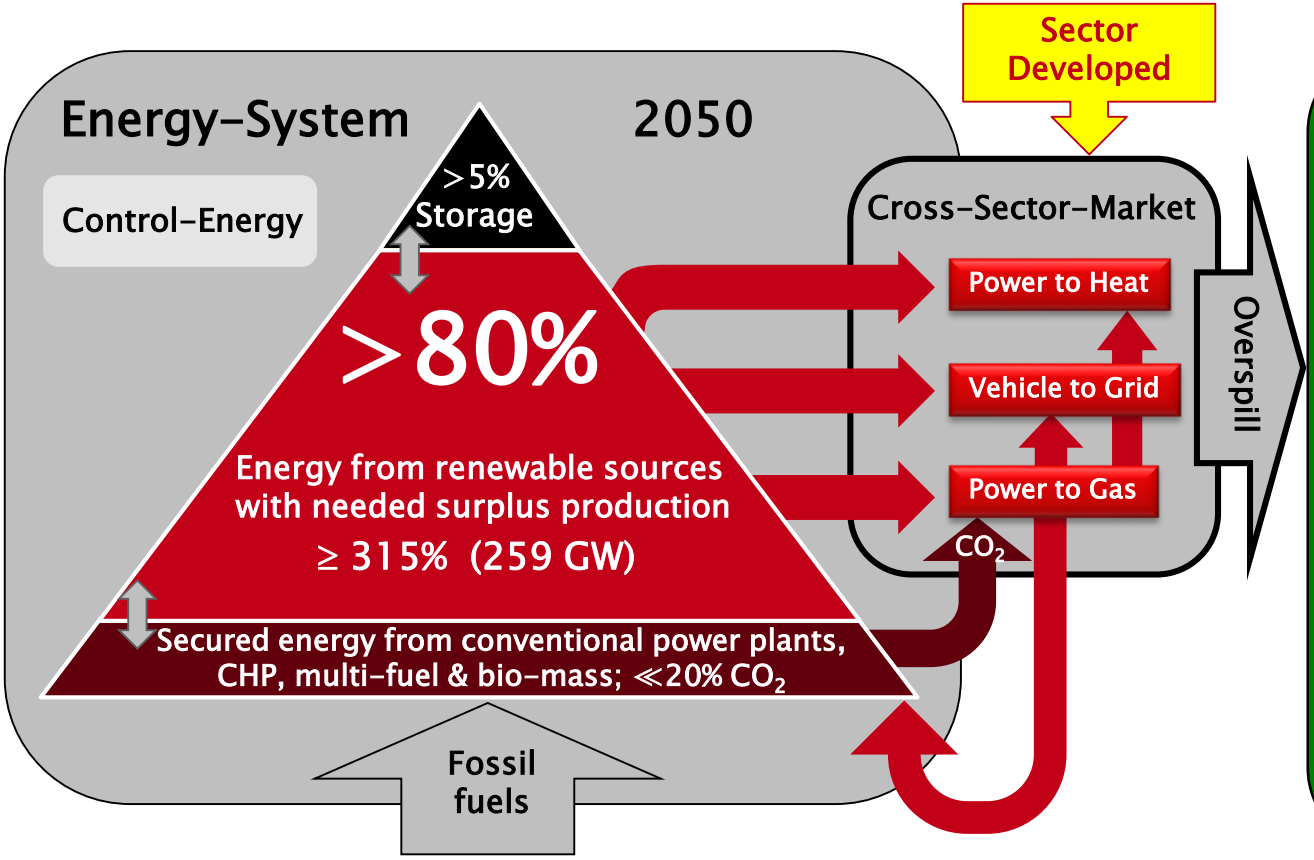
Increased RES share creates the shift from instant storage and load following technologies to long term high capacity storage.

- **Power to Fuel** is the best choice for long term, large scale energy storage.
- **LAES** is the only large scale electricity storage to be applied without any geological restriction both on brownfield and greenfield sites.



Future Market Development

Energy System in Germany – Prediction for 2050

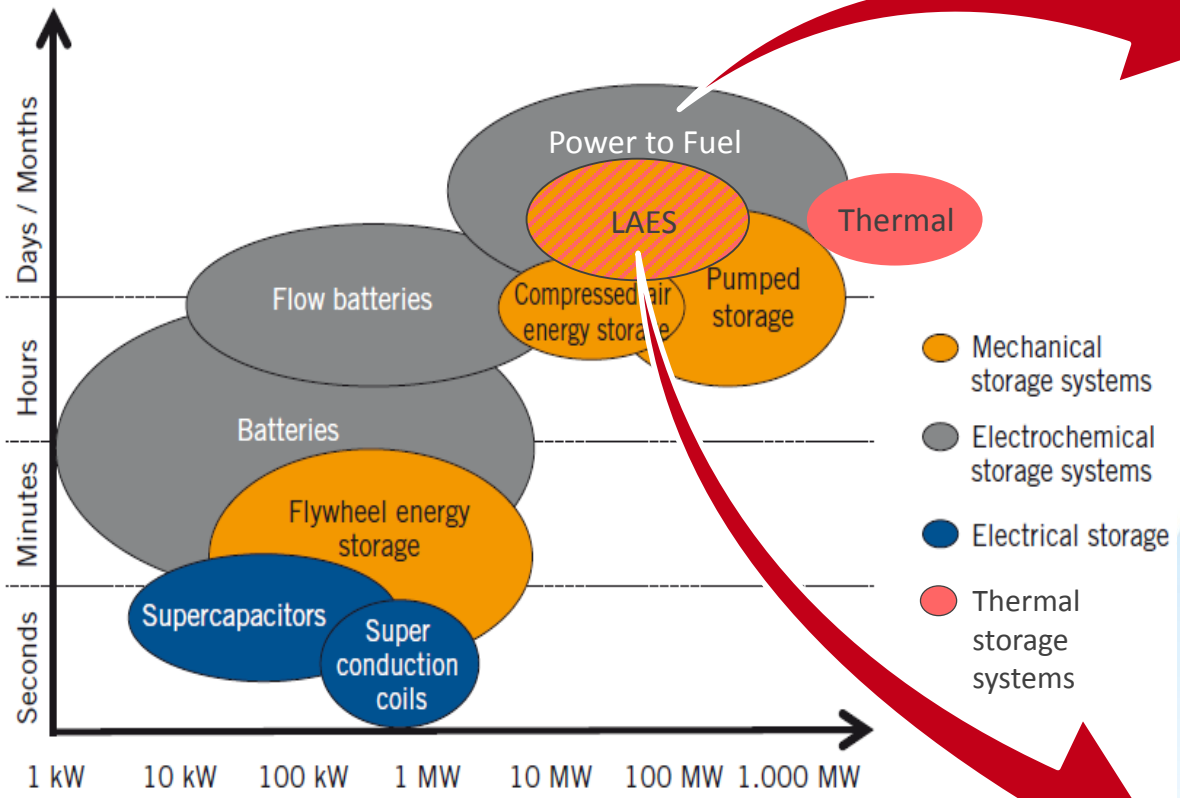


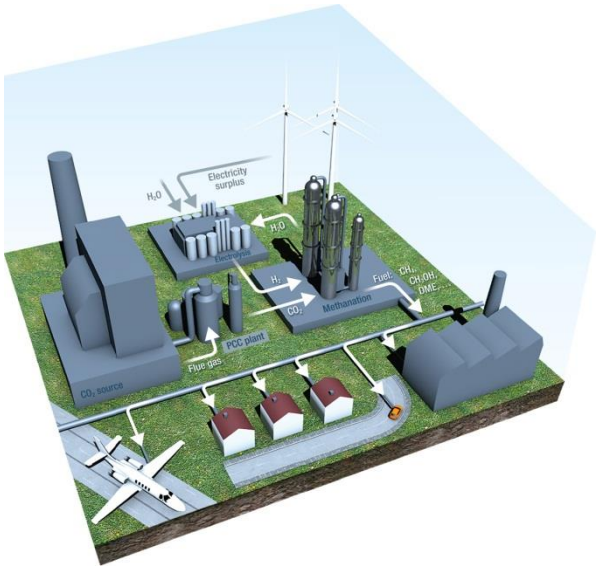
State 2050 (target)

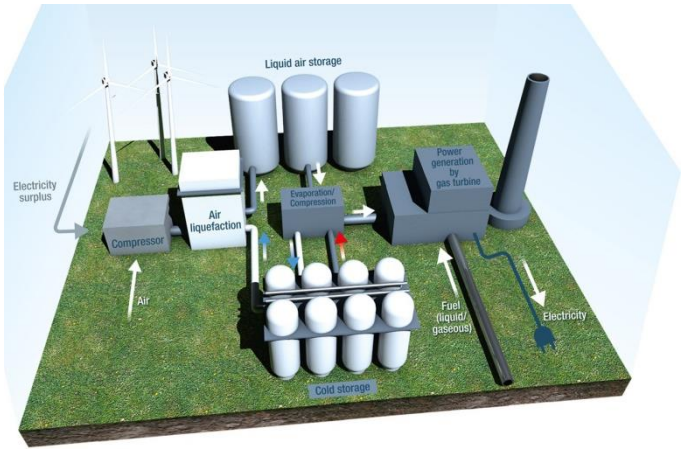
- 100 GW max. load demand
- 397 GW available capacity
- 59 GW conventional
- 259 GW renewables
- 14 GW storage
- 53 GW cross sector
- 12 GW biomass
- Load demand is expected to slightly rise until 2050 (13 GW)
- Demand Side Management to be planned and operated by big consumers
- Conventional power plant fleet to decrease to 50%
- electricity = a "cheap" commodity

Maximum load 87 GW + 13 GW in Demand Side Management (DSM)

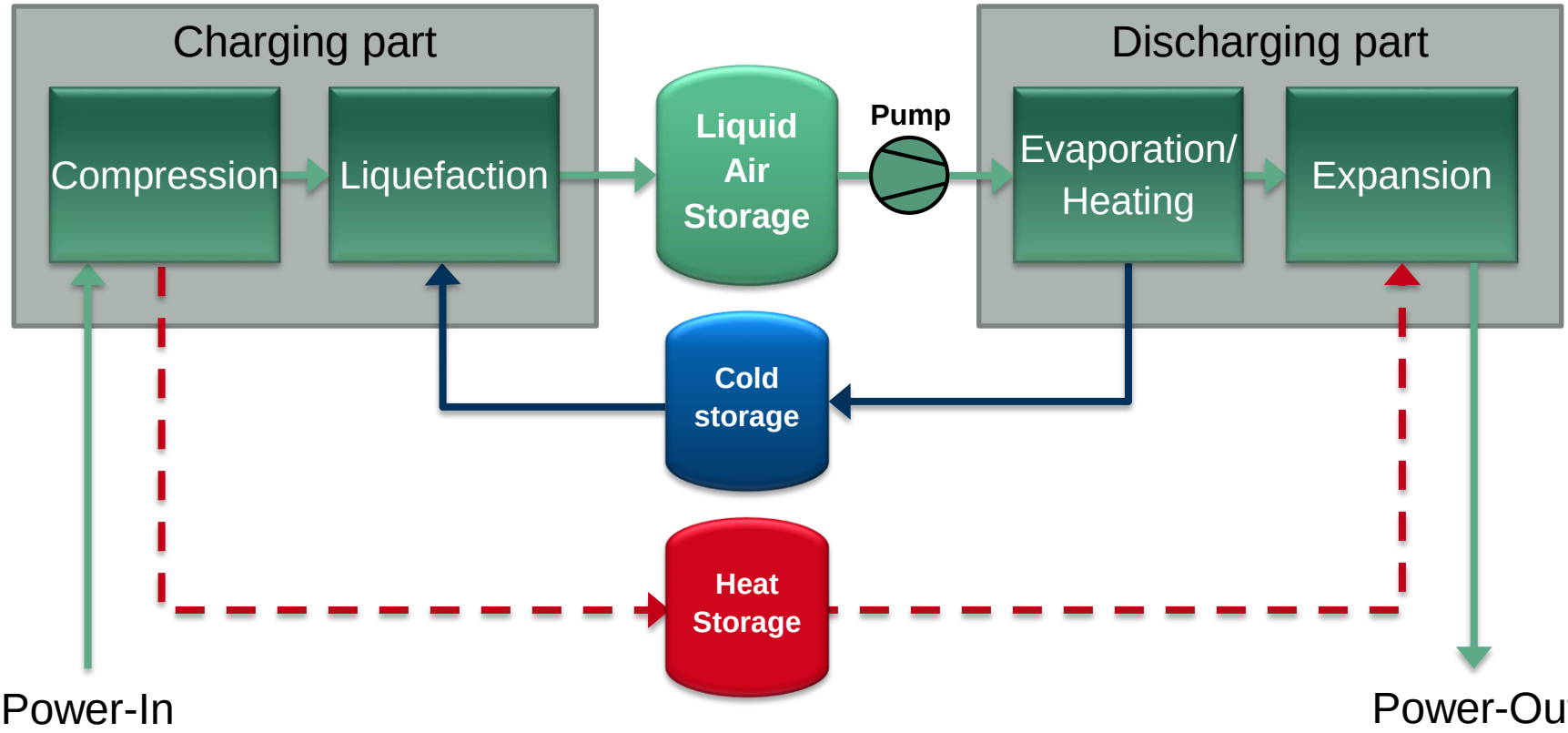
ES Technologies – Overview







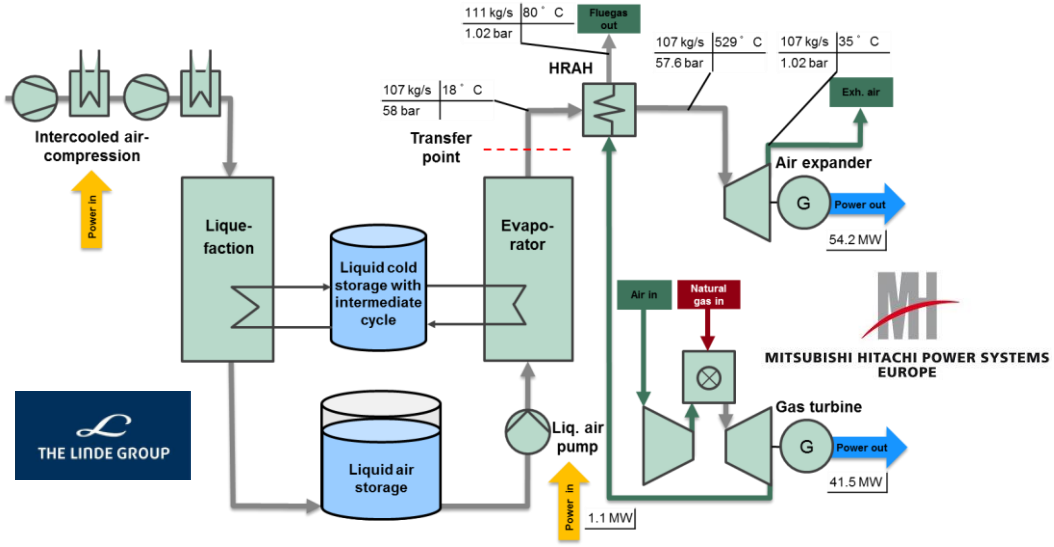
Liquid Air Energy Storage (LAES)



- Efficiency increase by integration of cold storage or industrial cold
- Solid bed cold storage
- Further efficiency increase by integration of heat storage or industrial heat

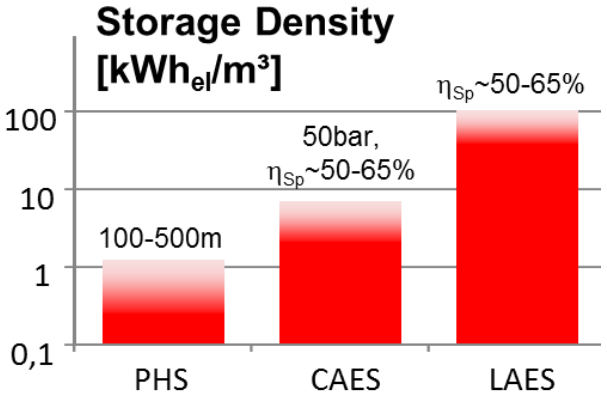
Liquid Air Energy Storage (LAES)

Bulk Electricity Storage and Back-up Power



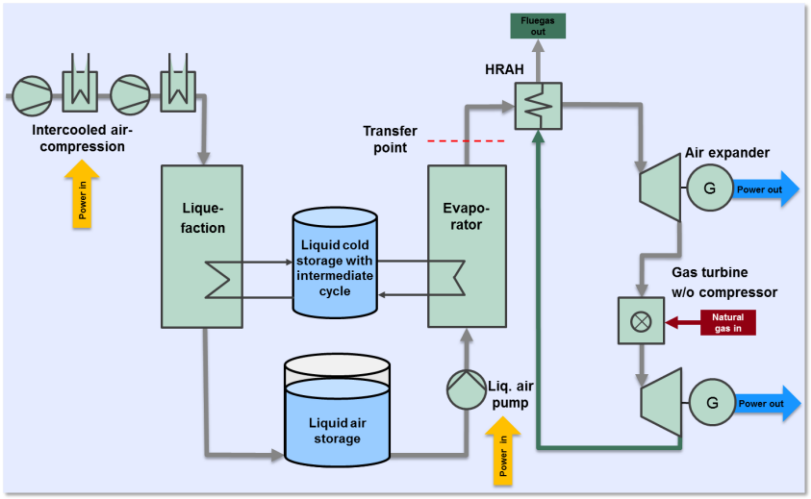
LAES is an energy storing technology, which is producing liquid air and heat (district heating) while charging and is producing electric energy from natural gas and liquid air while discharging. The efficiencies of this technology are **up to 65%** without district heating and above in case of considering also the produced heat as "used".

- **Joint development project** of Linde AG and Mitsubishi Hitachi Power Systems Europe GmbH (MHPSE)
  → combination of well **proven know-how** in terms of air liquefaction technology and power plant engineering
- Process Variant **GT-LAES**:
  - integrated gas turbine
  - based on **mature components**
  - combination with wide MHPSE gas turbine portfolio
    → **wide range** in possible LAES plant size (10-600MW)
  - possible combination with existing gas turbines and other high temperature heat sources (e.g. diesel engines)
    → **installation site flexibility**



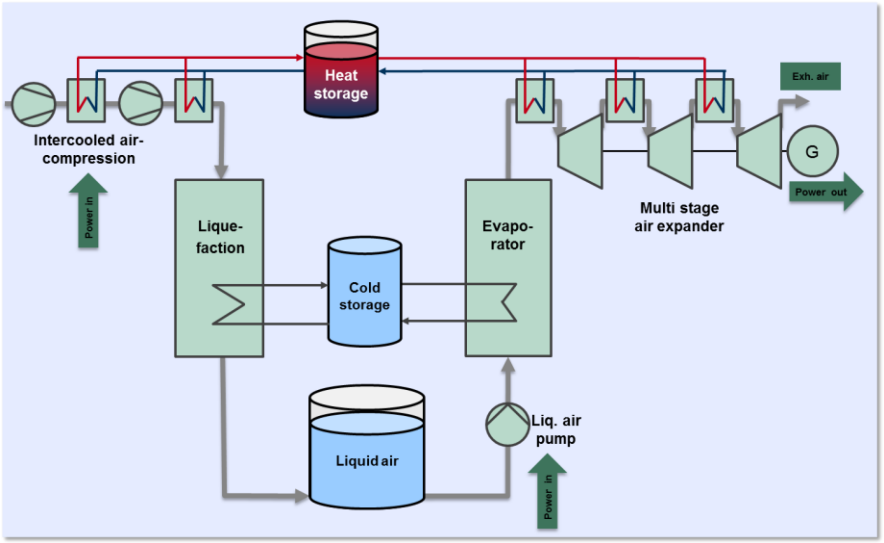
Liquid Air Energy Storage (LAES)

Generation 2 – higher Efficiency and adiabatic Systems



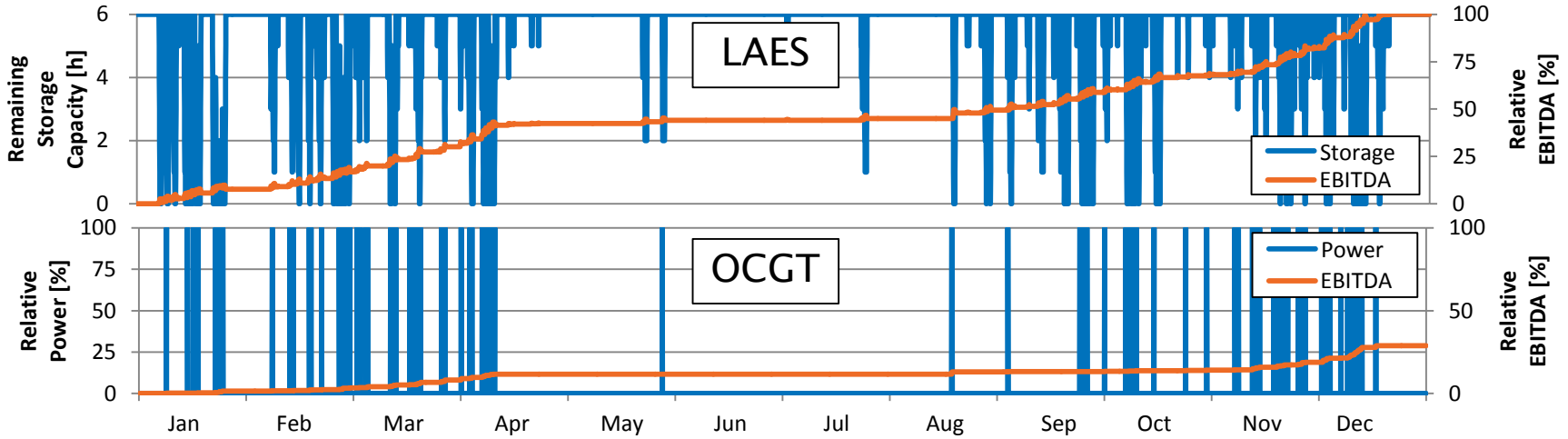
- Process Variant **Fuel-LAES**:
  - modified gas turbine w/o compressor parts
  - **increase in efficiency** of approx. 10 %-points possible
  - development issues for necessary equipment, especially **high temperature turbine**

- Process Variant **A-LAES**:
  - "A" for **adiabatic system**
  - no fuel use → **no CO_2 emissions**
  - Lower efficiency and power density as GT-LAES and Fuel-LAES expected
  - development issues for necessary equipment, especially **high temperature heat storage**



Liquid Air Energy Storage (LAES)

Enhancement of Operating Hours in Comparison to an Open Cycle Gas Turbine (OCGT)



Calculation based on PHELIX 2013 and NG price 27 €/MWh

Full Load Hours X 3

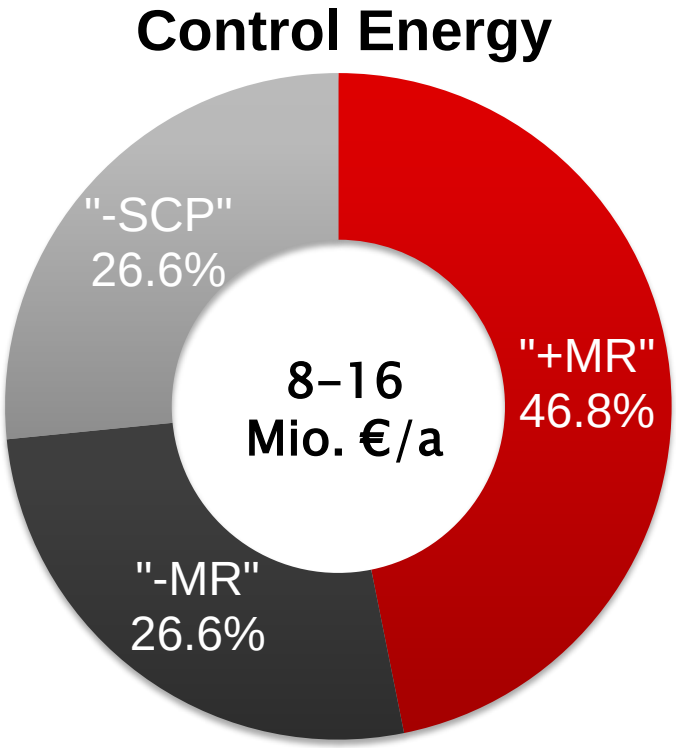
LAES: 527 h/a (discharging)

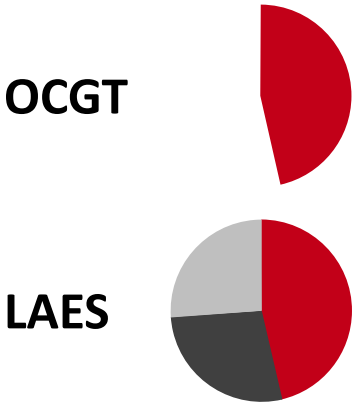
OCGT: max. 173 h/a

All Natural Gas consuming power plants are suffering from **high European gas prices**, compared to relatively low electricity prices. So is LAES with yearly EBITDA in arbitrage business < **1Mio. €**. In addition, **high PV capacity** inhibits economical operation of LAES and OCGT in **peak time hours**, especially in **summer months**.

Liquid Air Energy Storage (LAES)

Operation Flexibility of LAES enables broader Participation in Control Energy Market.





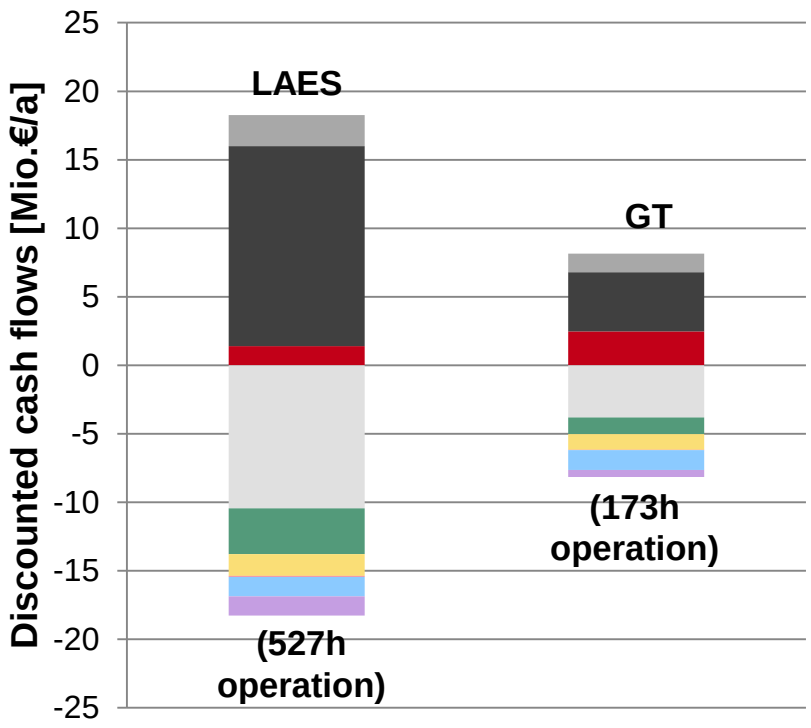
LAES can provide **negative Control Power** and thereby generates higher incomes compared with an OCGT. Further LAES can provide **back-up power**, even when the storage is "empty".

Calculation based on German Balancing Power Market 2010-2012; 90% Availability; 50% Award

"+MR"	positive Minutes Reserve (<15 min)
"-MR"	negative Minutes Reserve (<15 min)
"-SCP"	negative Secondary Control Power (<5 min)

Liquid Air Energy Storage (LAES)

Estimation of discounted cash flows and possible capacity premium



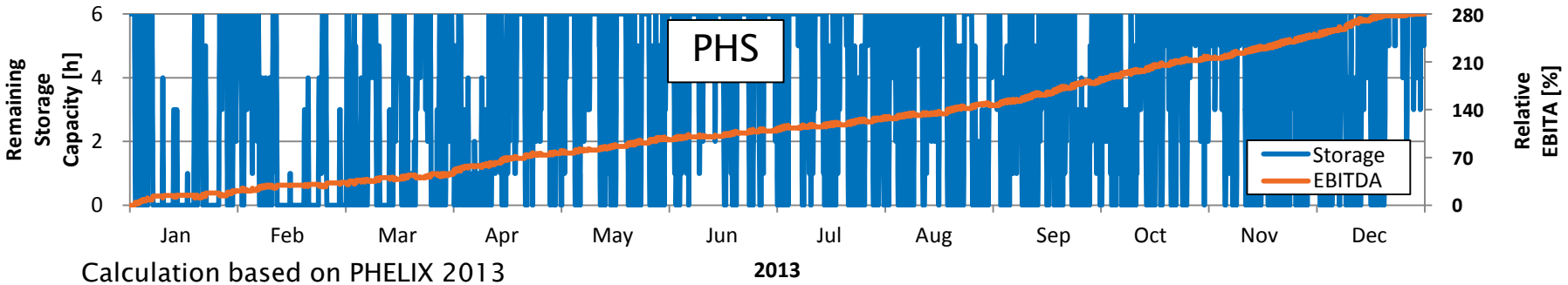
- Electricity wholesale market
- Control Energy market
- Capacity premium
- Dept capital annuity
- Equity capital interest
- Gas costs
- CO_2 certificates (~0)
- Staff costs
- Maintenance

Calculations based on German wholesale electricity prices (PHELIX 2013) and German control energy market data 2010-2012

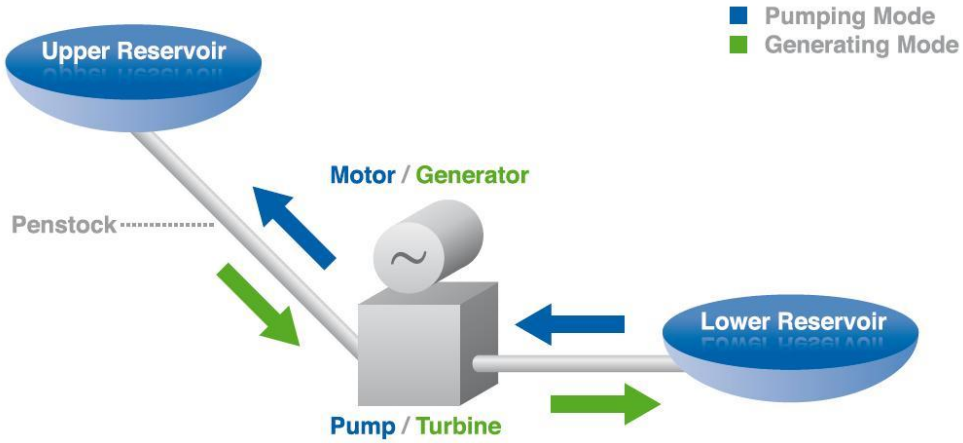
- Capacity premium causes compensation of yearly expenditures and incomes
- In spite of higher CAPEX the capacity premium for LAES is lower because of higher incomes from control energy market
- Incomes from electricity wholesale market are currently low, i.e. in this estimation 15-20 % of receipts

Pumped Hydro Storage (PHS)

Comparison of yearly yield and CAPEX



Calculation based on PHELIX 2013 and Efficiency 75 %



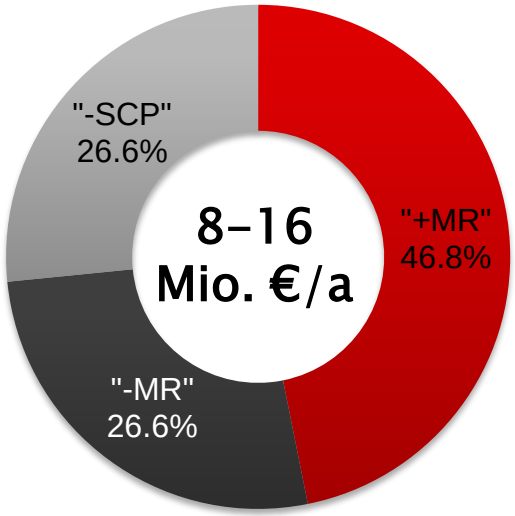
PHS can reach full load hours of approx. **~1500 h/a**, but EBITDA are also relatively low (< **2 Mio. €/a** from wholesale market). With capital costs of ~1000 €/kW **ROI** would be reached after **>45 years.** In comparison to LAES, PHS cannot provide back-up power and underlies **geologic restrictions.**

→ **Incomes from control energy market necessary for positive business case**

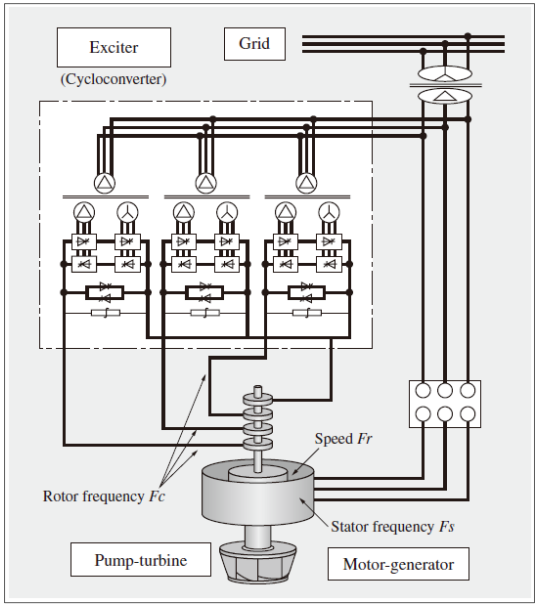
Pumped Hydro Storage (PHS)

What are the advantages of a PHS in the control energy market vs. other technologies

Control Energy of a LAES



"+MR"	positive Minutes Reserve (<15 min)
"-MR"	negative Minutes Reserve (<15 min)
"+SCP"	positive Secondary Control Power (<5 min)
"-SCP"	negative Secondary Control Power (<5 min)
"±PCP"	Primary Control Power (30 sec)



HM HYDRO
Quest for Nature's Potential

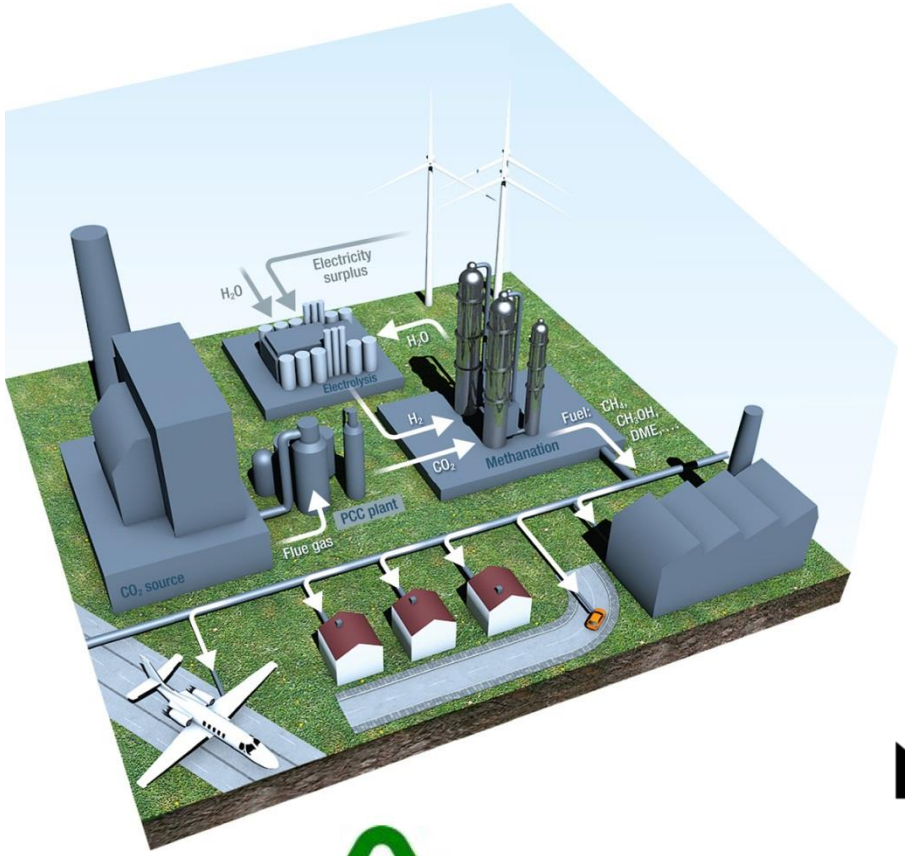
Due to its mature developed technology of variable speed controlled pumping and turbine mode PHS is able to serve all control energy markets including also +SCP and ±PCP. Therefore PHS is for ancillary services in advantage of LAES or even CAES, but still the LAES technology is also a back-up power plant and has no geological restrictions

First Conclusions

1. Today's energy market does not support large scale capacity energy storage systems
2. Regulatory constraints
   a. Dispatching order
   b. Pricing, e.g. subsidy similar to EEG (RES subsidy) or pure market
3. Market development
   a. Ancillary services mature
   b. Capacity payments limited importance
4. Technology screening to analyse first of its kind projects
5. All bulk storage technologies are not serving RES surplus production of more than 6 hours for this we need time shifting technologies like Power to Fuel …

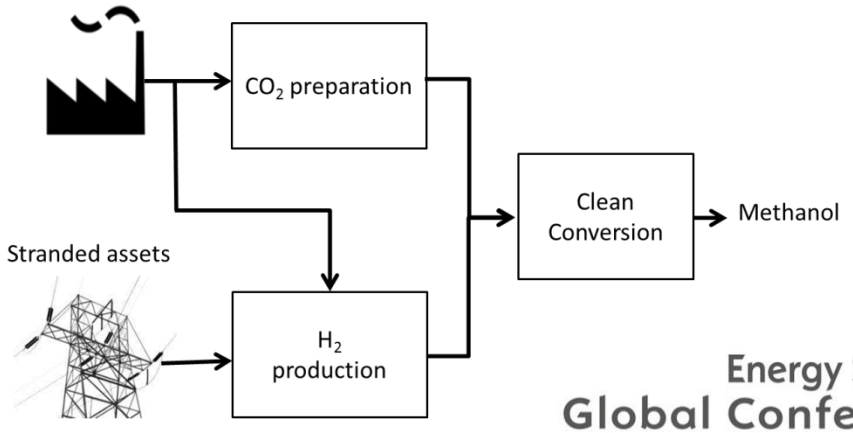
Outlook towards Power to Fuel(PtF)

Cross Sector Energy storing Technology



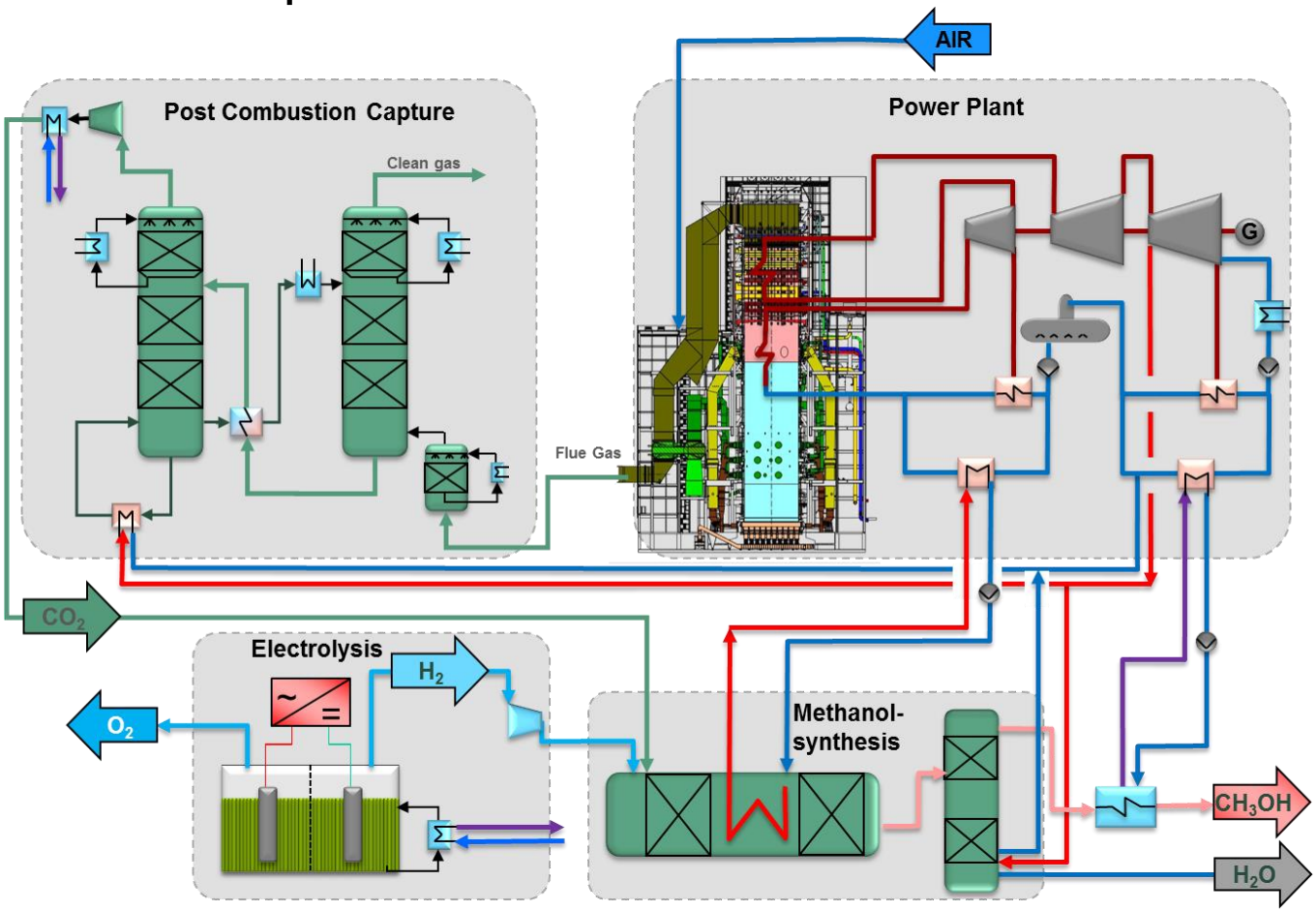
PtF is a cross sector energy storing technology, which is producing methanol and its following derivatives as olefins, gasoline, DME and other chemicals or transportation fuels. It is processing from electrical energy hydrogen and oxygen. The produced hydrogen is together with captured CO_2 processed to methanol with an exothermal process. The heat is used in the water steam cycle of an power plant for efficiency gain of the process. The efficiencies of the technology are **up to 67%** without the use of the oxygen in other processes. Using the oxygen this efficiency rises **up to 72%**, if it is used close to other industries using oxygen as one of its educts.

Carbon Recycling International

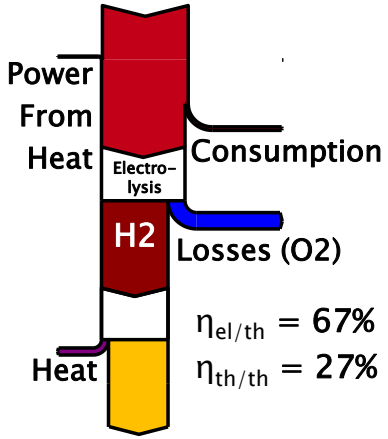


Outlook towards Power to Fuel(PtF)

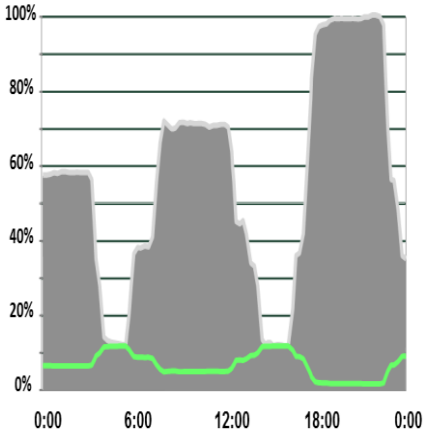
PtF in a Power Plant (Lignite) – A Flexibility Option with a Market for its Products.



474 MW_{th} Coal Consumption
191 MW_{el} at 30% Load



128 MW Methanol

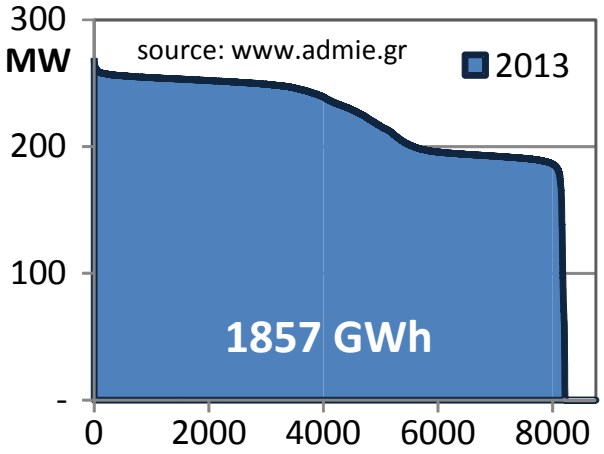


PtF keeps power plants in the business due to combined production.

Outlook towards Power to Fuel(PtF)

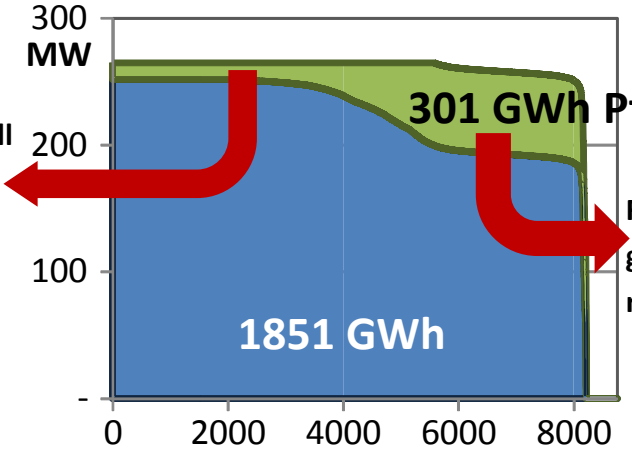
Retrofit Case of a typical 300 MW_{el} Class

A) Operation today, only electricity



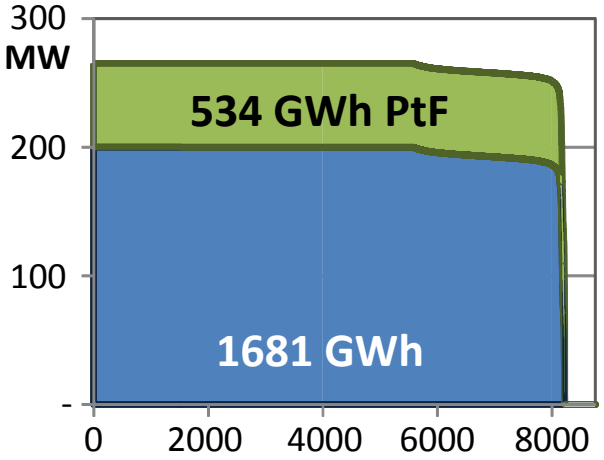
B) Operation with PtF, power-operated, 65MW electrolysis

Maintain only small base load of PtF during peak price times

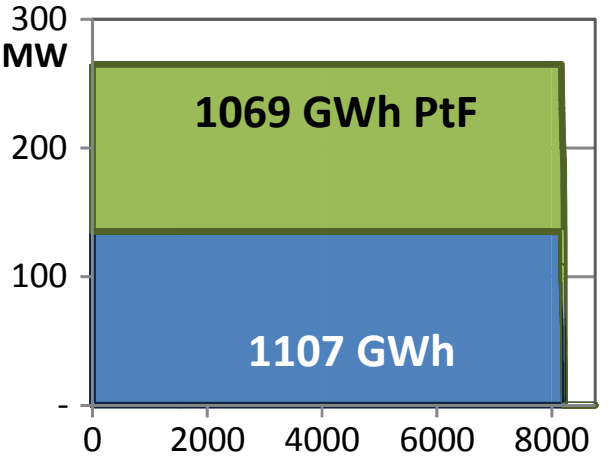


Fill the PP utilization gap created by (excess) renewable energy

C) Operation with PtF, MeOH-operated, 65MW



D) Operation with PtF, MeOH-operated, 130MW electrolysis

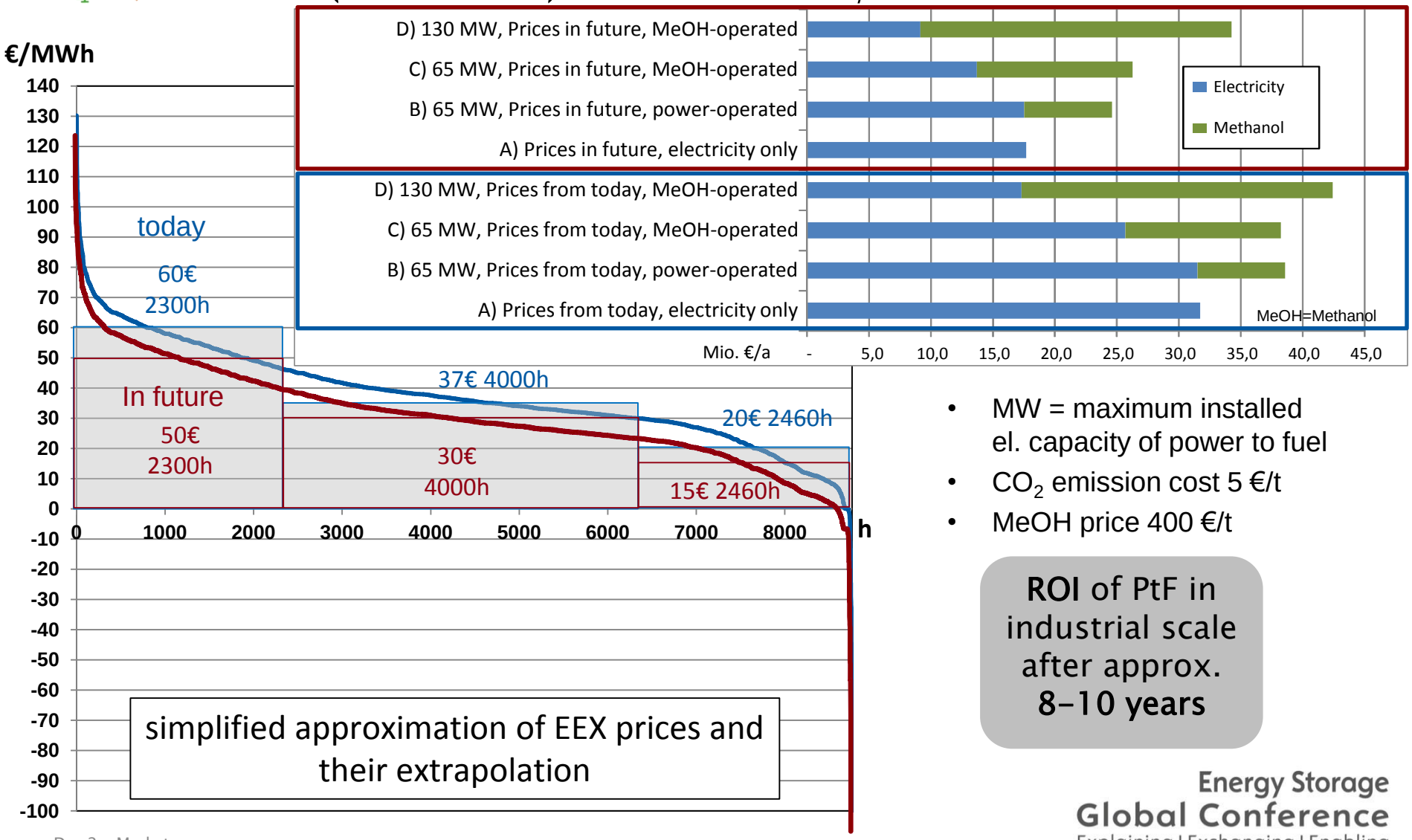


Greece Example:
Lignite with
4 MJ/kg

MeOH=Methanol

Outlook towards Power to Fuel(PtF)

Profit (Sales-Cost) without CAPEX/taxes

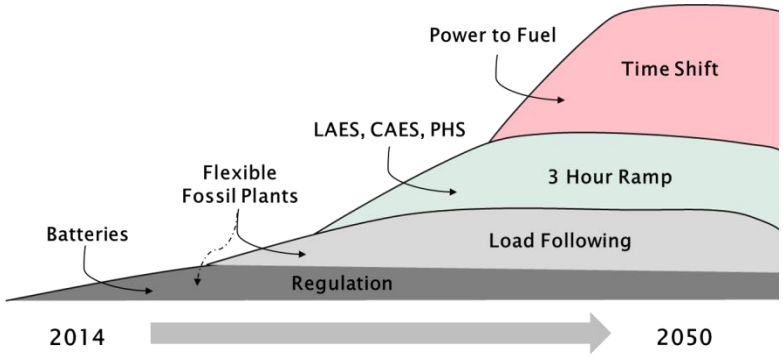


- MW = maximum installed el. capacity of power to fuel
- CO_2 emission cost 5 €/t
- MeOH price 400 €/t

ROI of PtF in industrial scale after approx. **8-10 years**

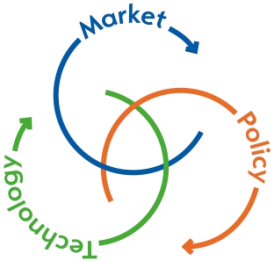
Final Conclusions

1. All storage technologies are necessary for the future



2. Mature bulk storage can be intelligent complemented hybrid-storage technologies like LAES

3. Power to Fuel Storage opens new sustainable markets and economic chances



Thank you for your attention