

Next-Gen Generation System:

The symbiotic relationship of solar, wind & storage hybrid power plants

PAULINA ASBECK
BATTERY@RENEWABLES
VATTENFALL

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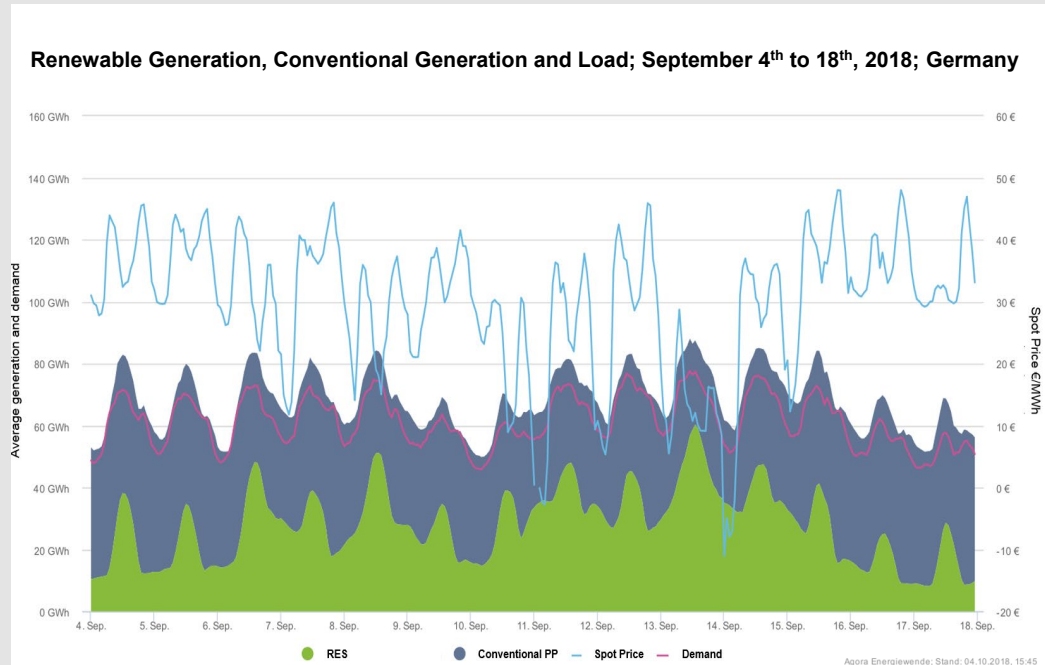
Vattenfall at a glance – fossil free in one generation

- One of **Europe's leading utilities**, focus on North-Western Europe
- **100% state-owned** by the Swedish state
- **20,000 employees** in Sweden, Germany, Netherlands, Denmark, UK, Finland
- **No. 1 Heat supplier** in Europe, largest district heating grid
- **One of the leading players in Offshore Wind** worldwide
- Strong in **Onshore Wind** and **Hydro Power**, recently entered **solar PV and Batteries**
- First **Hybrid Parks** in Operation (Solar + Wind & Wind + Battery), first Wind, Solar & Battery Hybrid under development



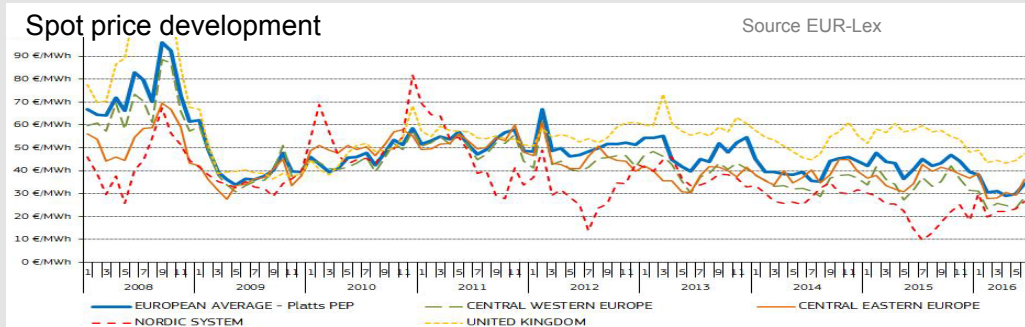
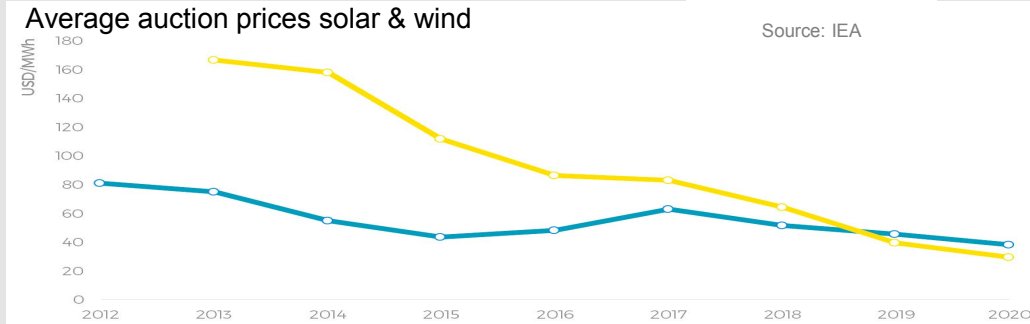
Challenges of renewable generation – rational for hybrid power plants

Fluctuating renewables are challenging – An example



- Fluctuating renewables cover 100% of demand on some days, but almost nothing on others
- Renewable supply is driven by weather not by the demand
- This can result in stress on the electrical grid, curtailment of renewable generators and low or even negative power prices

Fluctuating renewables get challenged



- Subsidies and spot market power prices have decreased, reducing revenues for renewable generation
- Reducing costs becomes essential
- Access to new markets can facilitate additional revenue streams e.g. ancillary services
- Flexibility in generation is required to optimize revenues

Advantages of hybrid power plants in combination with storage systems

Hybrid wind and solar installation come with advantages

Hypothesis

Infrastructure

- Joint usage of land reduces costs and contributes to local support
- Joint usage of grid and infrastructure (e.g. access roads) saves costs

Project Development

- Joint permitting process reduces risks and costs
- Shared resources reduce internal costs
- Joint site development reduces costs for e.g. soil investigations & weather measurements

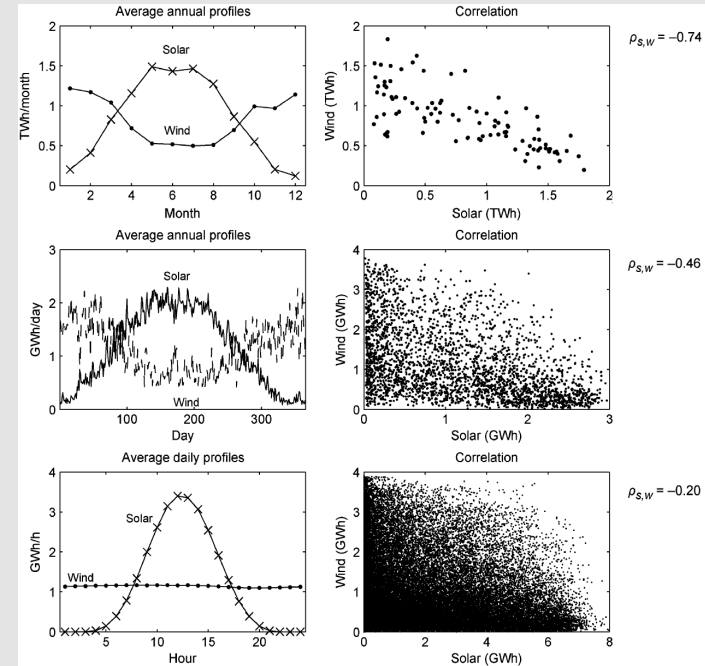
Park Performance

- More stable production curve increases utilization of the grid
- Batteries increase flexibility and number of accessible markets
- Forecasting errors can be buffered by batteries

COST REDUCTIONS & REVENUE INCREASE

Good correlation of wind and solar PV?

- Strong (negative) correlation of monthly wind and PV production in Northern Europe
- The stronger the negative correlation the better regarding e.g. utilization of the grid connection & balanced energy output
- Correlation decreases with diminishing time spans
- Our experience at the hybrid plant Park Cynog:
 - Monthly correlation: -0,89
 - Daily correlation: -0,32
 - 10-Min correlation: -0,15
- Adding a battery would improve the 10-Min, Hourly and Daily correlation
- Dimensioning of the solar and wind capacity is very important



Experiences with operational hybrid installations

Experiences from our first **wind and solar** installation:

- 8.4 MW onshore wind and 5 MW solar PV (2016, UK)
- **Synergies** from joint usage of land, grid and infrastructure
- First learnings of joint operation:
 - Higher (PV) curtailment than calculated, ratio of wind and PV is crucial, site-dependent
 - Some losses due to conflicting settings of controllers for active/reactive power
 - Fast reaction of controllers needed

Experiences from **wind and battery** installations:

- 122 MW onshore wind and 3 MW battery (2018, NL)
- 228 MW onshore wind and 22 MW battery (2018, UK)
- Synergies from joint usage of land, grid and infrastructure
- Challenging grid codes and metering concepts



Next step: application development 2.0

Operational applications

Today: Batteries provide grid services only, Generation assets trade energy on the energy market, little optimization

- Enhanced Frequency Response (UK), battery only
- Frequency Containment Reserve (NL & GER), battery only
- Joint use of infrastructure, separate market entries

Short term developments

Further integration of different assets at one connection point

- Imbalance trading & reduction of forecasting errors of wind and solar PV
- Provision of reactive power & black start capability with the hybrid park
- Optimization of the park performance
- Joint provision frequency reserve power

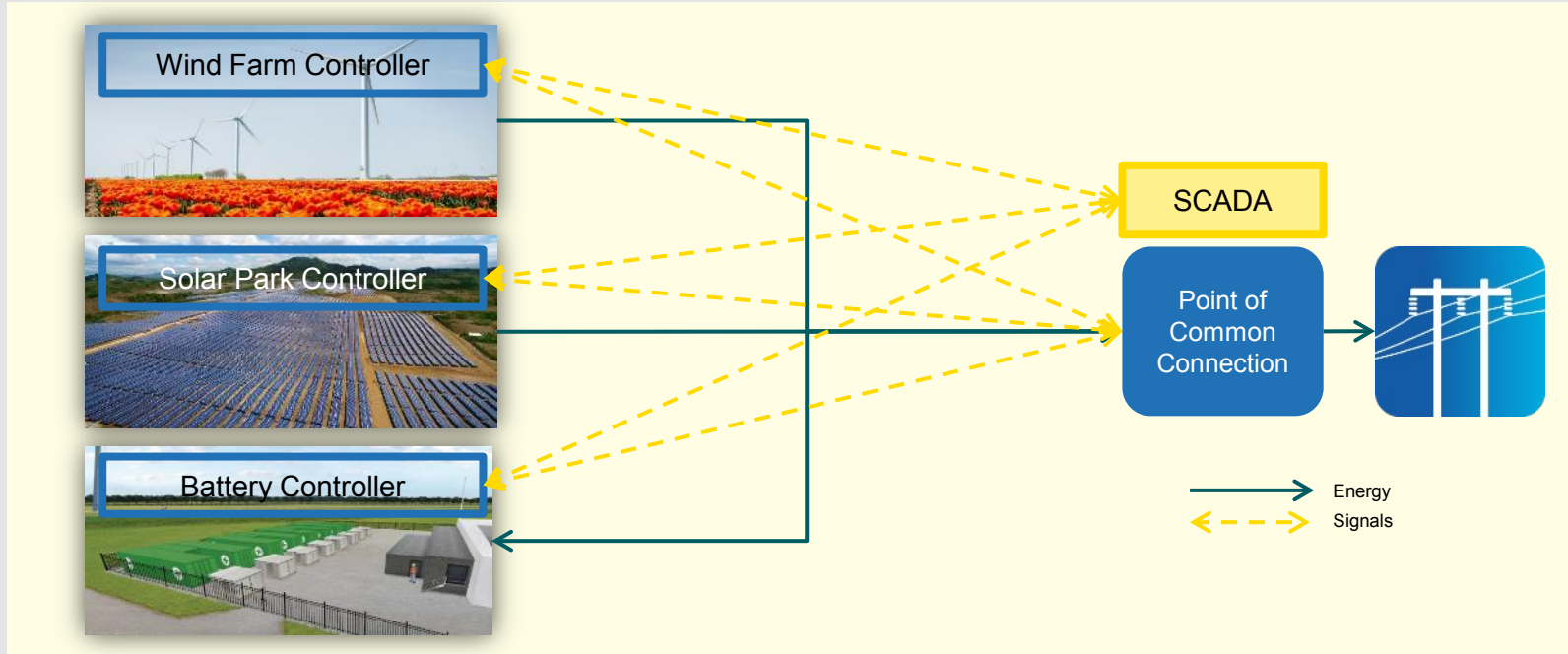
Goal: Integrated hybrid parks

Seamlessly integrated renewable generation assets that can be steered depending on demand and market situation

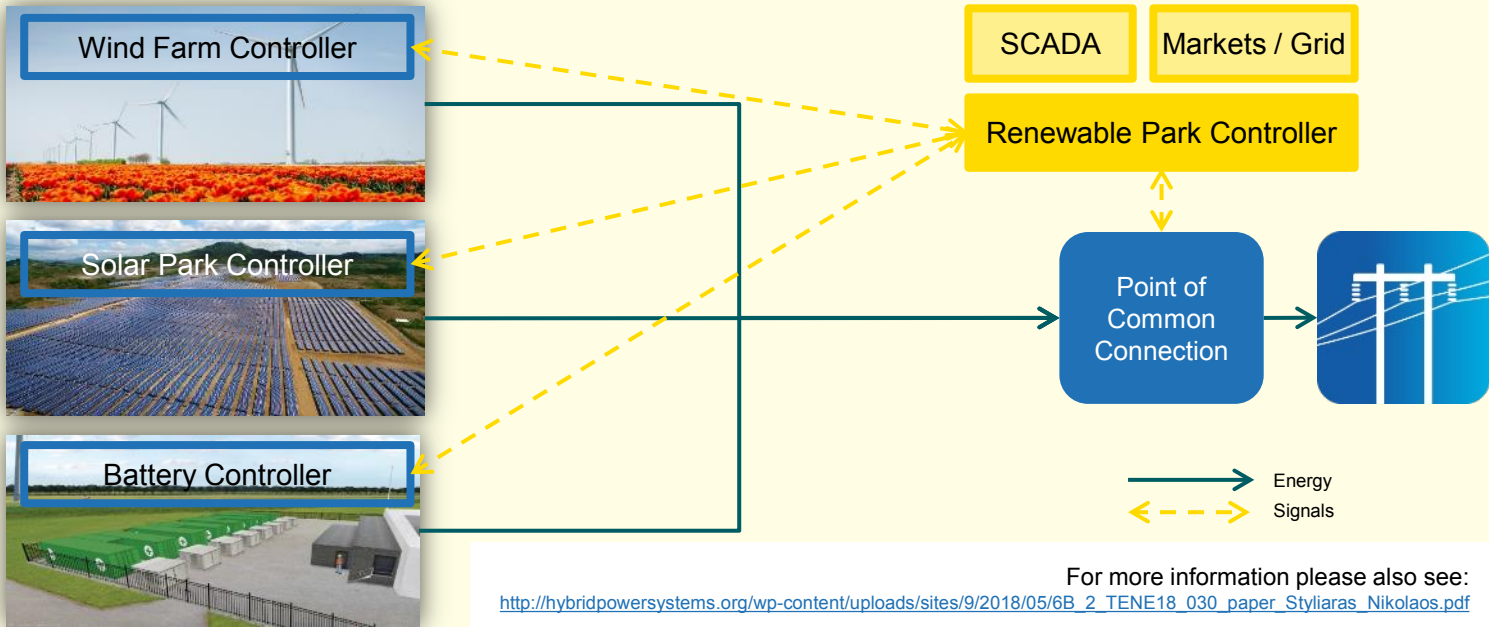
- Quarter-hourly optimization of the hybrid park (post subsidy era)
- Flexible participation on various markets: energy spot market, imbalance market, frequency control & other ancillary services
- How?

Technical Realization and Optimization

Technical setup of hybrid wind, solar and battery plant – OLD



Technical setup of hybrid wind, solar and battery plant – NEW



Conclusion

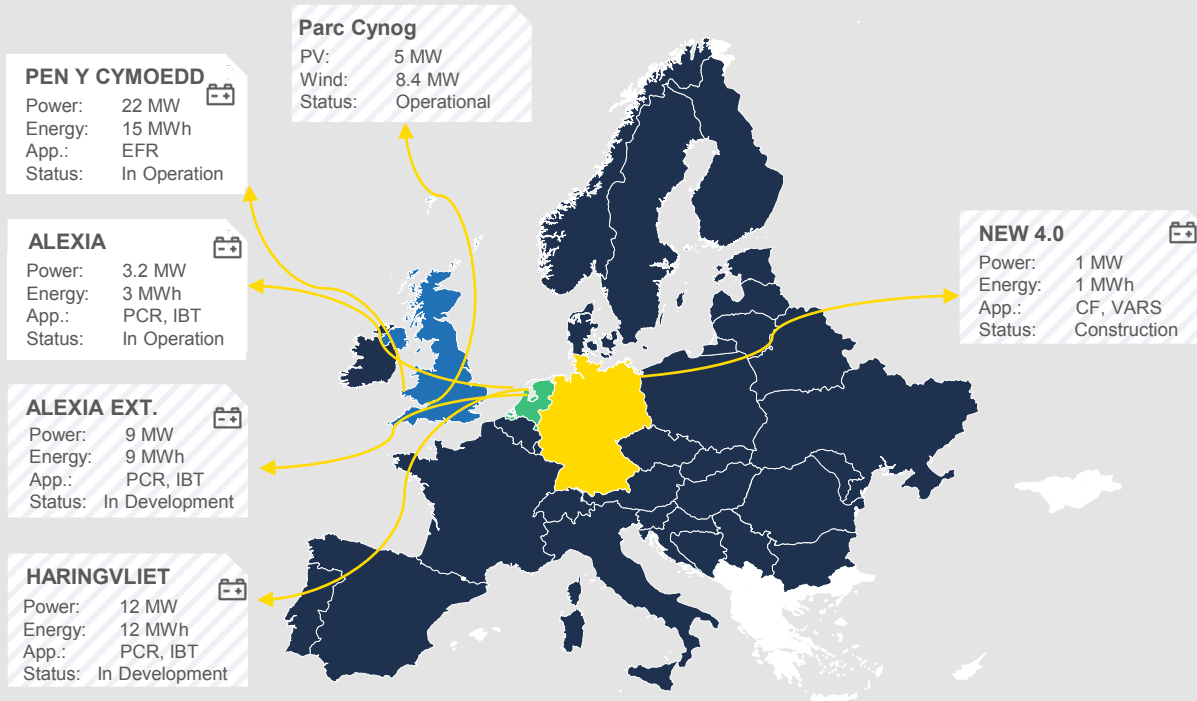
Main takeaways for hybrid wind and solar PV plant (plus battery)

- Declining subsidy levels & spot prices put cost pressure on renewable generation
- Co-location of wind and PV offers many advantages: smoother feed-in profile at grid connection point, joint development and permitting, joint usage of infrastructure like roads, substation, grid connection, etc.
- Addition of a battery can create extra flexibility and give access to other revenue sources like ancillary services, imbalance trading, etc.
- Ratio of wind and PV capacity is key, depending on site conditions and grid restrictions
- Controller settings are very important to optimise the business case, deep understanding of interdependencies, active/reactive power and electrical setup is crucial
- Intelligent and smart controller is beneficial for the business case, optimising all assets at the same grid connection depending on production, price and weather signals

Thank you!

Backup

Track record hybrid power plants



LEGEND:
PCR – Primary Containment Reserve
IBT – Imbalance Trading
PS – Peak Shaving
EFR – Enhanced Frequency Response
CF – Capacity Firming
VARS – VAR Support