HYDRO

HYBRID SOLUTIONS
THE FUTURE ENERGY

JULY 2019

ANDRITZ

ENGINEERED SUCCESS

WE ARE FACING A DRAMATICALLY CHANGE IN THE GLOBAL ENERGY MARKET

A challenge for maintaining the high level of energy security

TPP Neurath / Germany

From a few mostly fossil fuel or nuclear generation

To a carbon-free renewable generation

Challenges:
Liberalization (production – distribution)
energy market (primary – secondary, day ahead),
Base load - peak load, Volatility,
weather forecast, smart meter

THE FORMER MAIN ENERGY GENERATION WAS BASED ON THERMAL AND NUCLEAR

Advantages

- Proven technology
- Large centralized assets
- Large inertia
- Base load capability (day ahead)
- Weather independent

Limitations

- CO_2 emission
- No renewable source of energy
- No flexibility

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WIND – OLD TECHNOLOGY FOR THE MODERN WORLD

Advantages

- Proven technology
- On-shore/off-shore
- Quick project development
- Peak load capability (intraday)

Limitations

- Currently max. 12 MW / wind mill (off-shore; diameter: 200 m)
- Volatile resource - Weather depending
- Base load capability (day ahead)

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SOLAR – THE FASTEST GROWING ENERGY TECHNOLOGY

Advantages

- Lowest equipment price – easy to install
- Quick project development
- Peak load capability (intraday)

Limitations

- 20,000-30,000 m^2 / MW
- Volatile resource - Weather depending
- Base load capability (day ahead)
- Lifetime

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HYDRO – MOST EFFICIENT RENEWABLE SOURCE OF ENERGY

Advantages

- Proven technology
- Base load capability
- Cheapest LCOE (Levelized Cost of Electricity) over Lifetime

Limitations

- Depending on specifics of individual hydro location
- Long project development time
- Higher investment (80% civil works incl. dam)
- Peak-load capability (for run-off river HPP`s)

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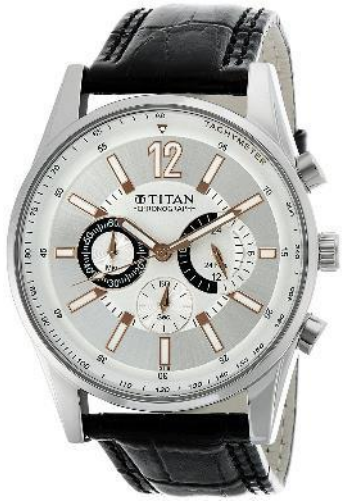
HOW WE CAN REALIZE THE ENERGY TRANSITION, PROTECT THE ADVANTAGES AND SKIP THE LIMITS?



Developing and Using of a Hybrid solution!

WHAT DOES HYBRID MEAN?

In it most basic sense – Mixture!

Technology – Automobile industry

- Hybrid drive of engine and battery
- Advantages:
  - Fast response
  - Energy recovering (braking)
  - No CO_2 emission

Biology - Mule

- offspring of a male donkey and a female horse
- Advantages:
  - more patient, hardy and long-lived than horses
  - less obstinate and more intelligent than donkeys

Plants - Pluots

- combination of plum and apricot
- Advantages:
  - sweet flavor and texture of a plum
  - exterior has the fuzzy, soft feeling of an apricot

LARGE SCALE HYBRID SOLUTION ARE THE FUTURE OF THE POWER INDUSTRY

Definition

- Main Features:
  - two or more different power generation technologies
  - at least one (!) renewable energy source
  - combined power and energy storage system

- Targets:
  - Higher level of energy security (stability)
  - Grid support to compensate volatility
  - Storage capacity for new asset opportunities to participate in the energy market
  - Extension of equipment life time – reduction of mechanical stress

The future has already began

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EL HIERRO / SPAIN
SELECTED LARGE ENERGY HYBRID SOLUTION

Energy security for the entire population by combining wind and hydro

- Facts:
  - Gorona del Viento located on El Hierro (second smallest Canary Island)
  - 1,458 km far away from mainland, 5,000 families
  - Risk of fuel supply in periods of stormy weather

- Project story (Wind and Hydro):
  - Installation of a hybrid solution to secure electricity supply (11.5 MW wind; 6/12 MW pump/turbine mode)
  - 4x Pelton turbines (2.8 MW each) provided by **ANDRITZ**
  - Successfully inaugurated in 2014
    - On August 9th, 2015 100% renewable energies were used for the first time for 4 hours
  - Reduction of 6,000 tons of diesel and 19,000 tons of CO_2 during the next 20 years

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KIDSTON / AUSTRALIA
SELECTED LARGE ENERGY HYBRID SOLUTION

Storage capacity to realize the world‘s first "base load renewables" project

- Facts:
  - Northern Queensland, 2,400 km north of Canberra
  - Existing large solar farm (270 MW) and abandoned Gold mine
  - Planned wind farm (150 MW) - wind generation profile correlates inversely with solar generation

- Project story (Solar, Wind and Hydro):
  - Installation of a hybrid solution to compensate wind and solar drops and provide base load renewable supply
    - 270 MW solar (150 MW wind in future)
    - 250 MW pumped storage (capacity for 8 hours)
  - **ANDRITZ** – selected supplier for hydro- and electromechanical equipment for pumped storage plant
  - Project starts in 2020

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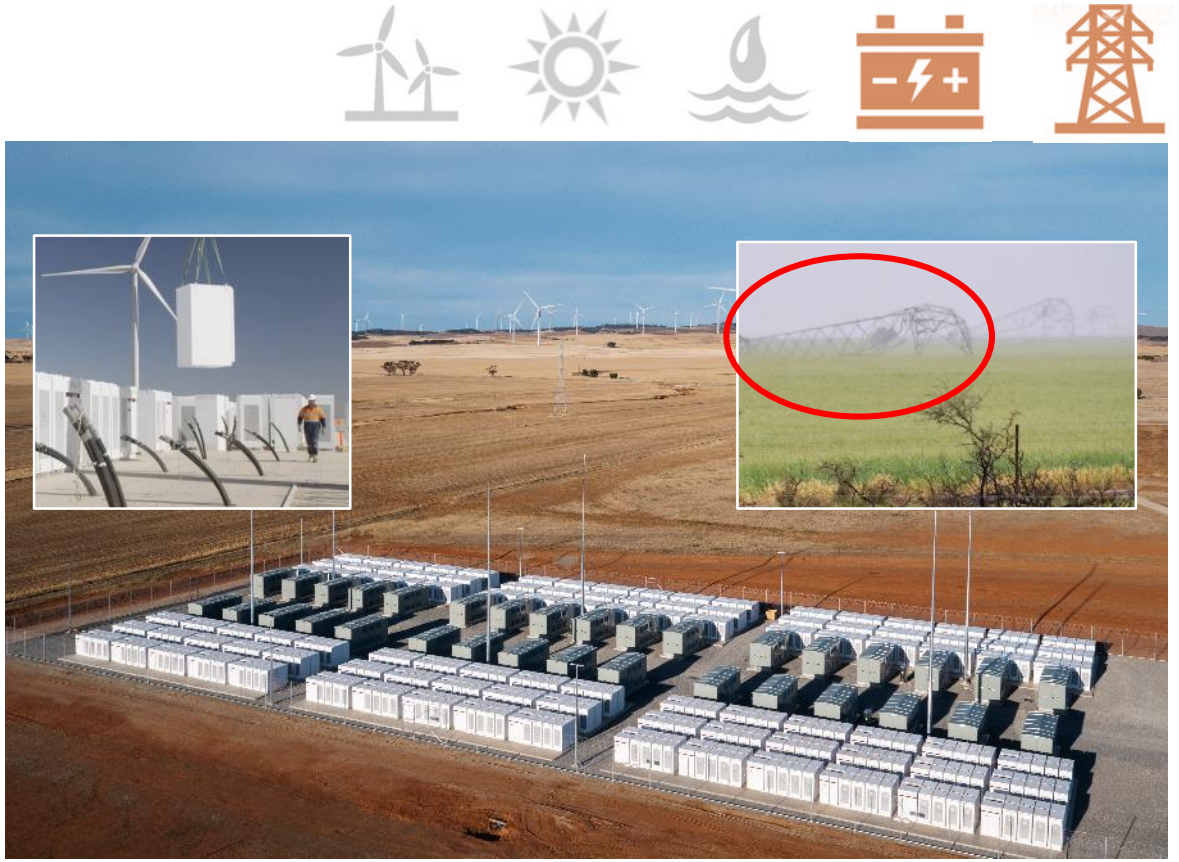
HORNSDALE POWER RESERVE / AUSTRALIA SELECTED LARGE ENERGY BATTERY SOLUTION

Balanced grid energy and blackout prevention by using industrial available Mega-Battery Plants

- Facts:
  - South Australia, 1,200 km West of Canberra
  - Heavy storm created Blackout in Sept-28, 2016
    1.7 mio people over 980,000 km^2 were effected
    - South Australia has been crippled by electrical problems in recent times

- Project story (Battery and Grid):
  - Installation of an industrial mega greenfield battery plant (100 MW) close to an existing wind farm
  - power up 30,000 homes for an hour (fully charged)
    - Lithium ion battery
  - Built by **Tesla** within 100 days (!)
  - Successfully inaugurated by end of 2017



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WHAT ARE THE HYBRID SOLUTIONS OF ANDRITZ?

We develop and provide

- Large Scale Hybrid Solution
  combining hydropower assets and several renewable energy sources, like wind, solar, and hydro

and

- Integrated Hybrid Solutions
  as part of our hydropower core competences
  to improve and expand your business cases

    - For extension of life time
    - Stabilizing the grid
    - Storage and shift energy over the day

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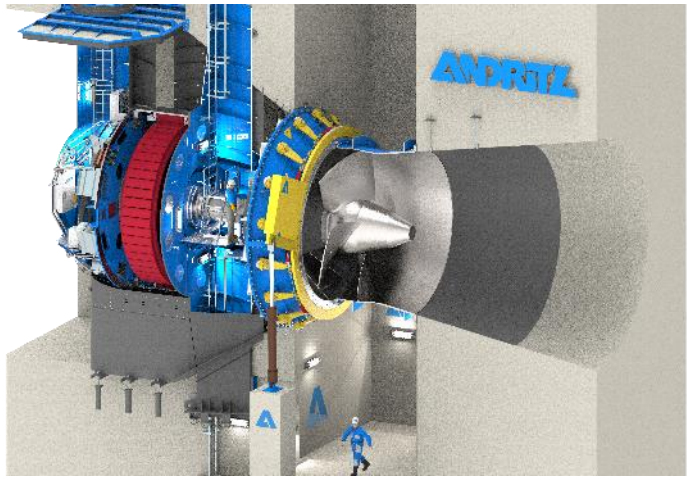
OUR DEDICATED HYBRID SOLUTION FOR THE HYDROPOWER INDUSTRY

Combining the advantages of hydropower and battery technology



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Advantages:
- High efficiency
- Proven technology
- Smooth operation
- Renewable source of energy

Advantages:
- Short term storage capacity
- Fast response time
- Highest flexibility
- Load balancing

Advantages:
- Wider energy range
- Fastest response time
- Flexible power
  (also in part load at start-up)
- Highest operational flexibility

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HYBATEC – TYPICALLY APPLICATION CONCEPTS BASED ON THE TODAYS ENERGY MARKET

General operation concepts of your hydro asset

Life time

- Feature:
  - Battery compensates small frequency fluctuations
- Advantage:
  - Reduced mechanical equipment movements (less stress)
  - Dramatically lifetime increase of bearings, servomotors, etc.
  - Smother turbine operation and transition

Grid

- Feature:
  - Short-term energy (< 1 hour) capacity by the battery
- Advantage:
  - Enabler for the participation in the energy market (additional revenues)
  - New investment opportunity for low head assets (!)

Storage

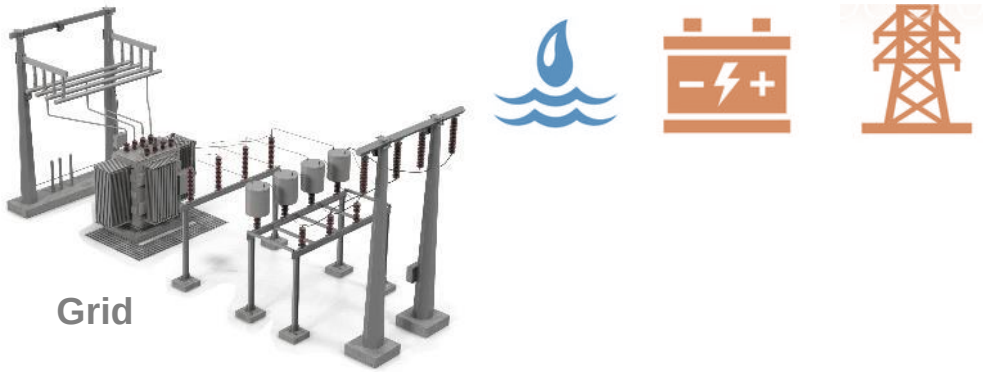
- Feature:
  - Battery based mid-term storage capacity (1-4 hours)
- Advantage:
  - Energy shifting and peak load shaving (additional revenues)
  - Optimized hydro unit size
  - improves fish friendly operation (change of operation point)
  - Black start asset

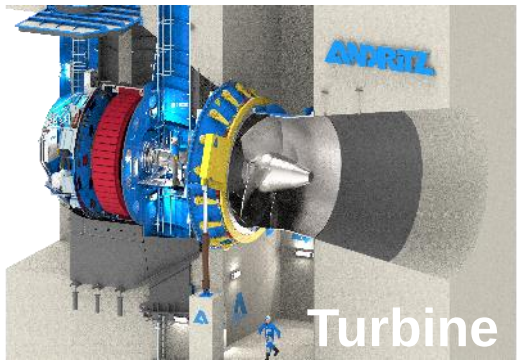
HYBATEC – THE DIFFERENT OPERATION MODES

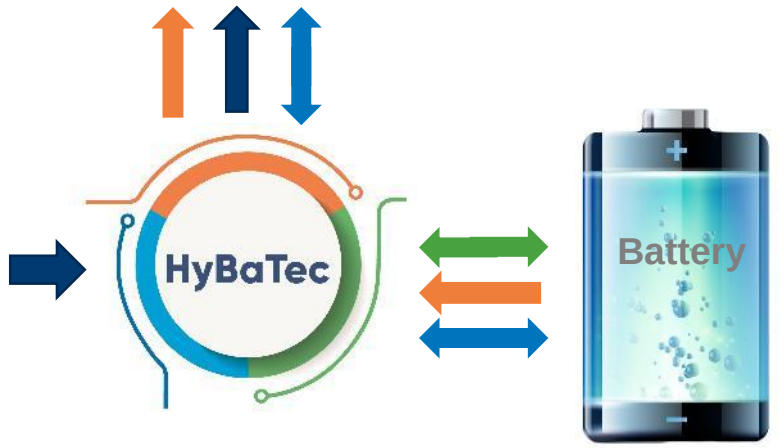
Life time extension:
- Turbine operation based on long-term feed-in tariff
- Battery capacity <2.5% of installed turbine capacity
- Quick grid volatility charges/discharges the battery
  -> smother operation of the mechanical equipment

Grid support:
- Turbine operation based on long-term feed-in tariff
- Battery capacity 5..20% of installed turbine capacity and >1MW (e.g. precondition of the EU energy market)
- Short-term grid energy balancing realized with battery based on short-term energy contracts

Storage and Energy shift:
- Turbine operation based on long-term feed-in tariff
- Battery capacity depending on storage definition for energy and time; 15..25% of installed turbine capacity







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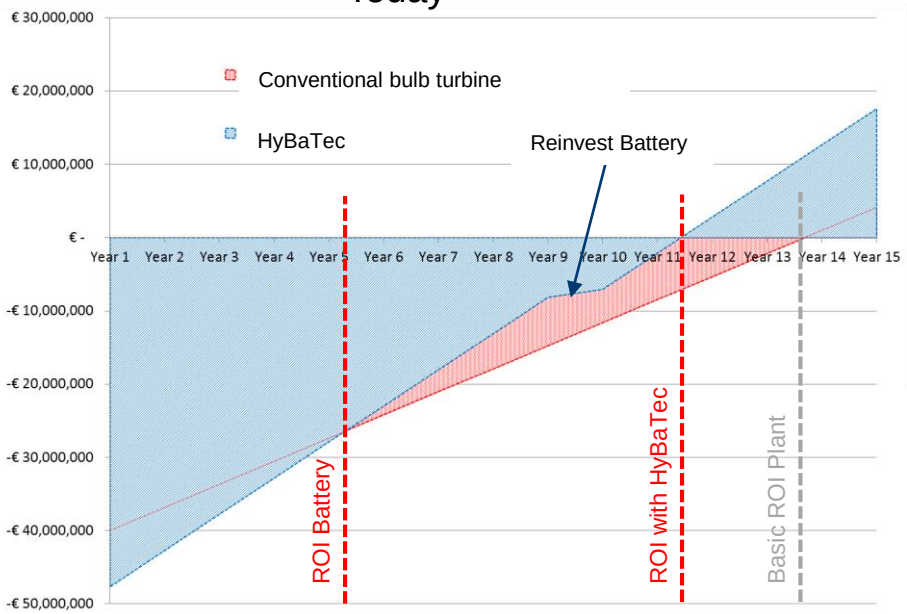
HYBATEC OFFERS NEW POSSIBILITIES FOR THE ECONOMIC FEASIBILITY OF YOUR INVESTMENT

ROI example and possible impact of future energy price

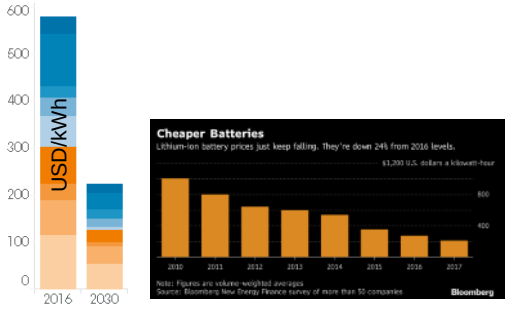
Today



- Battery: ROI after 5 - 6 years
- HyBaTec: ROI 2 years earlier compared to conventional application

Energy price [MWh]

Battery price [kWh]



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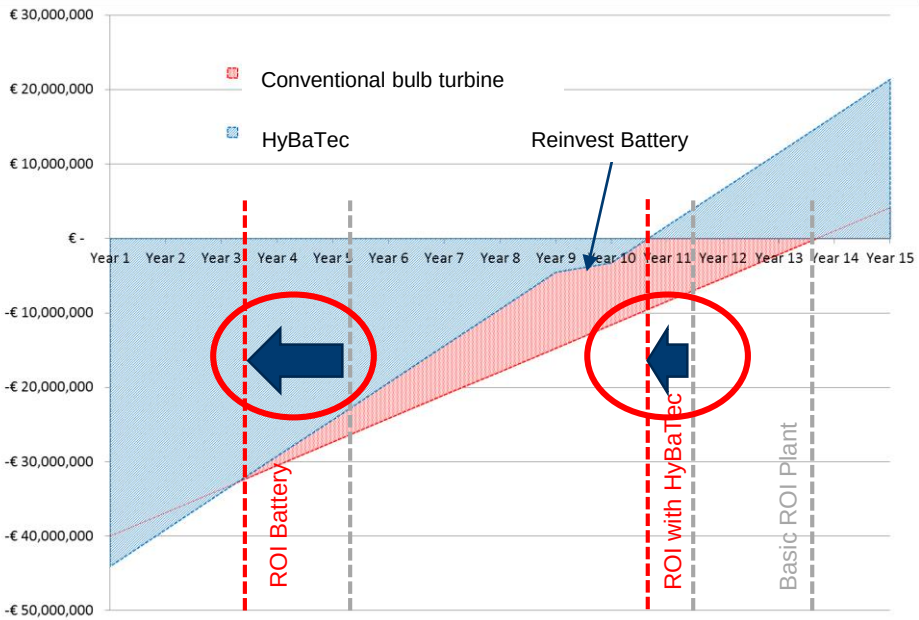
New battery after 7,000 Load cycles are considered adequately
Only energy arbitrage is considered
Additional revenue streams are not considered

Future



- Battery: ROI after 3 - 4 years
- HyBaTec: ROI 3 - 4 years earlier compared to conventional application

*1 – Source: IRENA Electricity Storage Costs 2017;
Cost reduction potential for Li-Io-battery
*2 – Bloomberg; Cheaper Batteries

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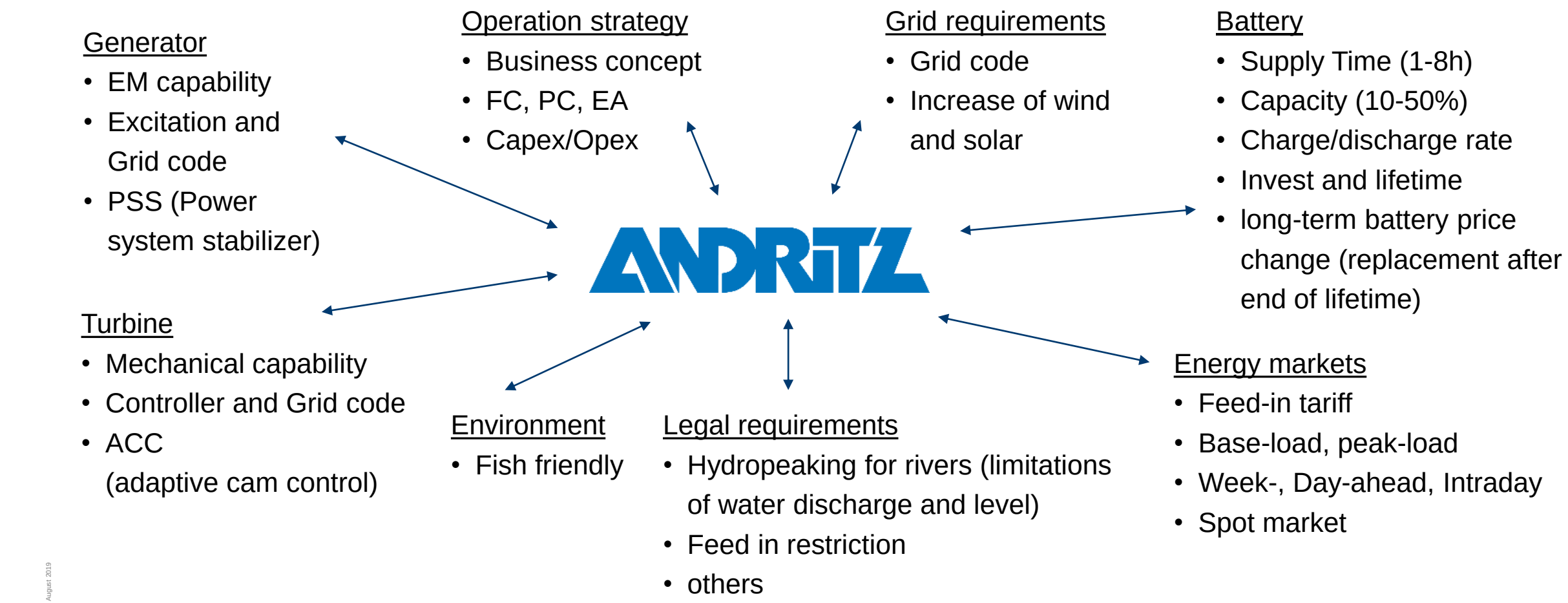
WE ARE YOUR PARTNER TO DEVELOP AND REALIZE THE BEST HYBRID SOLUTION FOR YOUR BUSINESS

HyBaTec is more than a battery – it´s a solution based on long-term experiences and know-how



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PILOT PROJECT

Using a battery to open new opportunities for the existing hydropower plant

- Facts:
  - Run-of-river power plant (10 MW installed capacity)
  - Main Target: Ancillary Service (Primary Control)

- Project story (Hydro and Battery):
  - Installation of a hybrid battery-turbine solution,
  - while rehabilitating existing electromechanical equipment
  - Battery capacity approx. 10% of installed turbine capacity
  - Full battery power available for 1 hour (primary control)
  - Hybrid solution provided by **ANDRITZ**

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SUMMARY

ANDRITZ is your partner for your hybrid solution!

- Hybrid solutions are the future of energy market
- Large scale hybrid solutions:
  Combination of wind, solar, hydro, and pumped storage to balance the volatility and enable competitive “renewable base load”
- Hybrid solution for hydropower assets:
  HyBaTec - Battery based solution for run-off river HPP’s
- HyBaTec offers new asset opportunities for:
  - Greenfield hydro - smaller dimension, more capacity
  - Hydro rehabilitation - upgraded capacity, lifetime extension
  - Small hydropower - upgraded capacity, lifetime extension
  - Rural and inhabited areas, Island operation applications

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