

# Pumped hydro Storage Plants

Olivier Teller, Product Director PSP

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POWER

**ALSTOM**

**>130 GW**

(99% world electricity storage)

**Market: 6 GW/year**

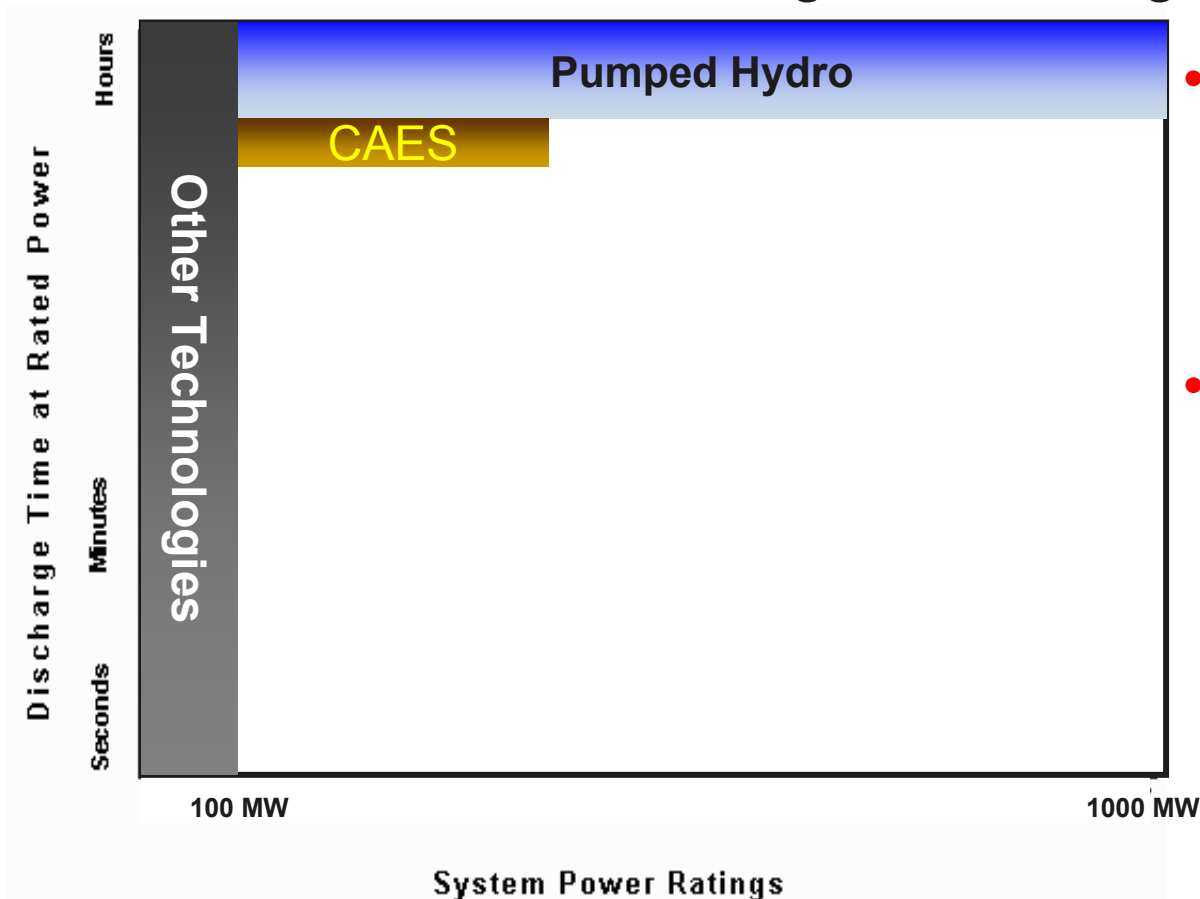
Europe: ~1.5GW/year

**100 years / illimited cycle numbers**

**~1000 €/kW**

500€ - 2000€/kw

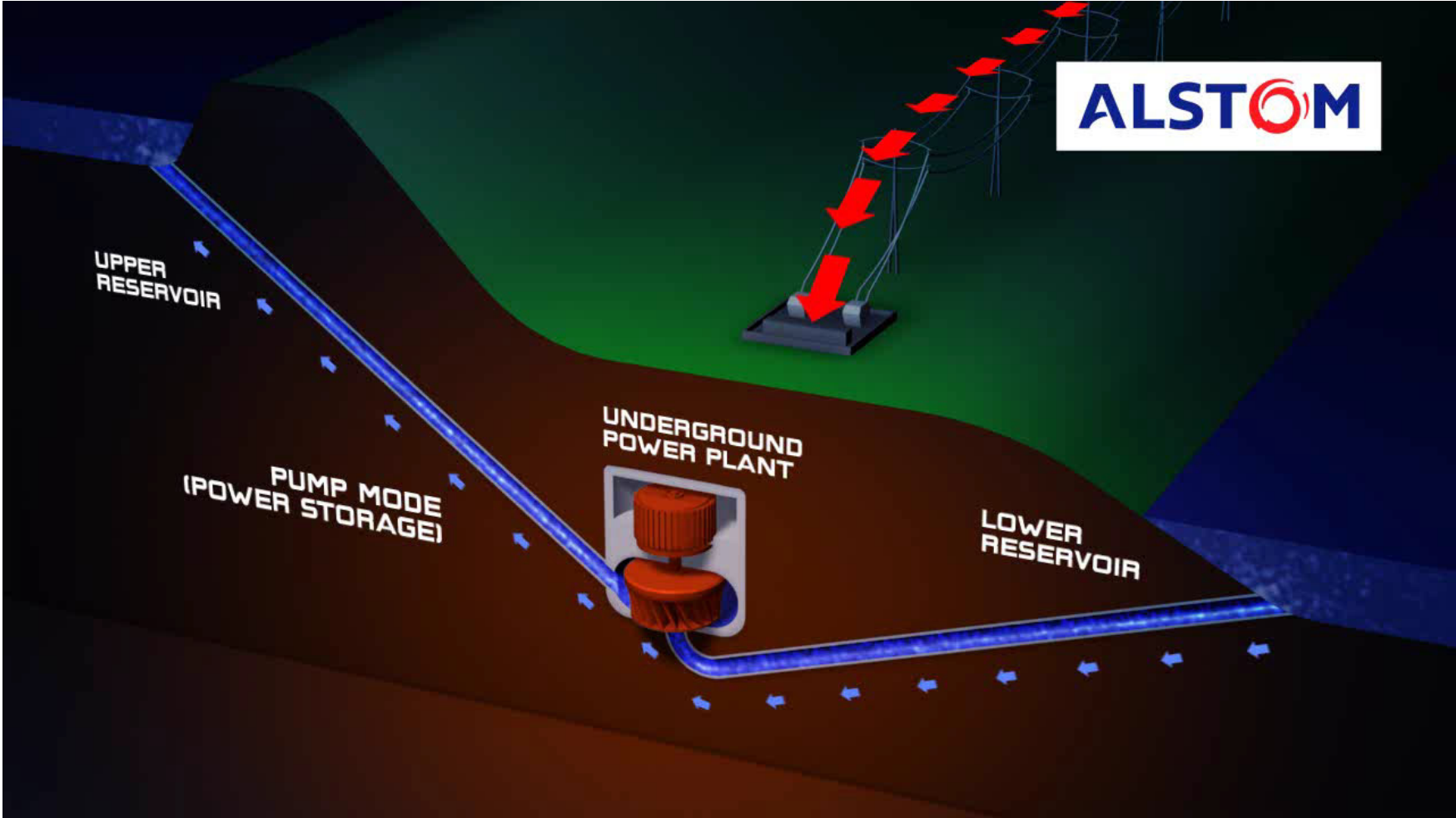
## Storage Technologies



Source: [www.electricitystorage.org](http://www.electricitystorage.org)

- Technologies must correspond to power and capacity requirements
- Large Energy and Power
  - PSPs
  - CAES

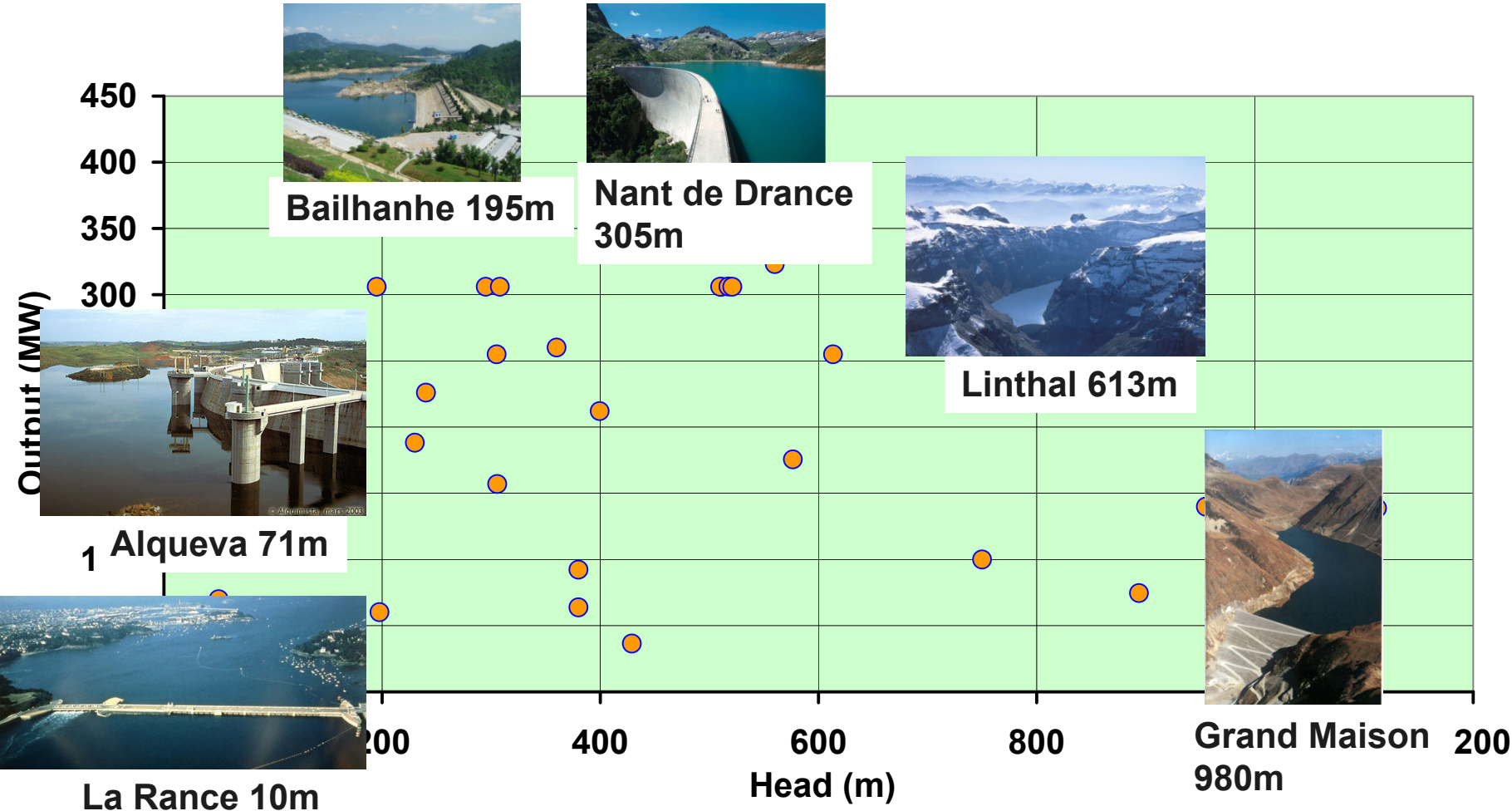
Global efficiency ~ 80 %



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# Pumped Storage Plants





Solutions from 3 to 1200 m head

## PSP key facts

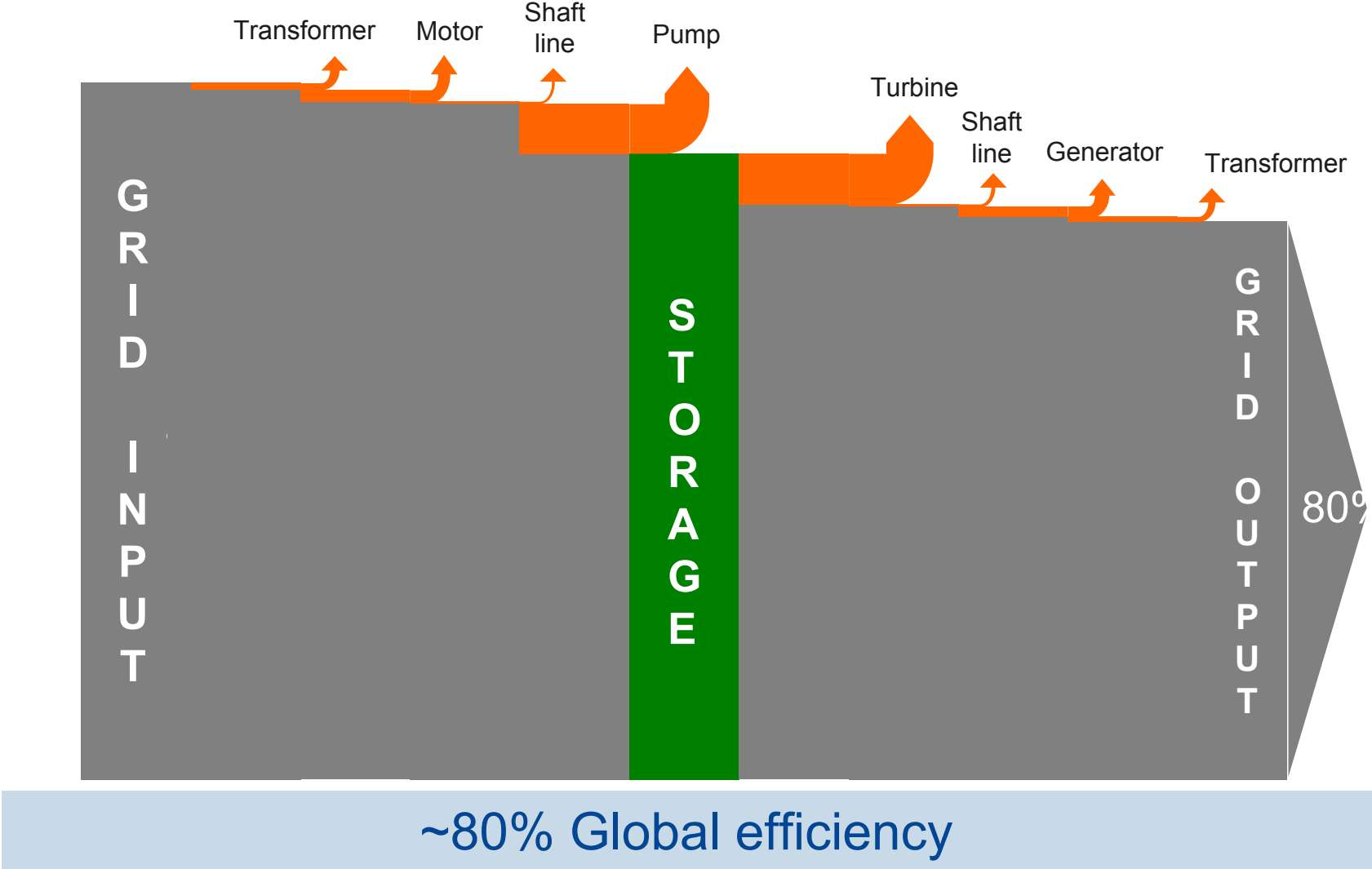


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<b>General Performances</b>	<b>5 to 500 MW</b>	Output/Input
	<b>&gt; 8 hours full load</b>	Storage capacity
	10 to 2000 m.	Head Range
	> 80%	Cycle efficiency
<b>Reaction Time</b>	<b>~ 15 s.</b>	50% to 100% Generation
<b>Ancillary Services</b>	<b>25% to 100%</b>	Production adjustment range
	<b>70% to 100%</b>	Pumping power adjustment range (Variable speed machines)

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# PSP global energy balance



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# PSP Key development drivers



## Thermal & Nuclear

Fixed power production

Match production & consumption



## Renewable

Time Shift

Shift the excess production to provide the peaks

Firming

Compensate non predicted power variation thanks to fast power adaptability



## Transmission

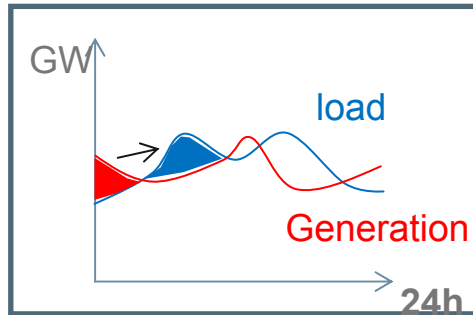
Close to production

Suppress peak from intermittent production

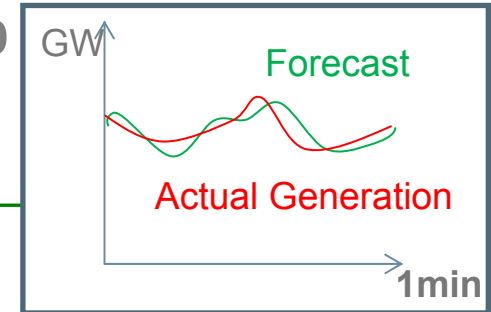
Close to consumption

Smoothen peak from consumption

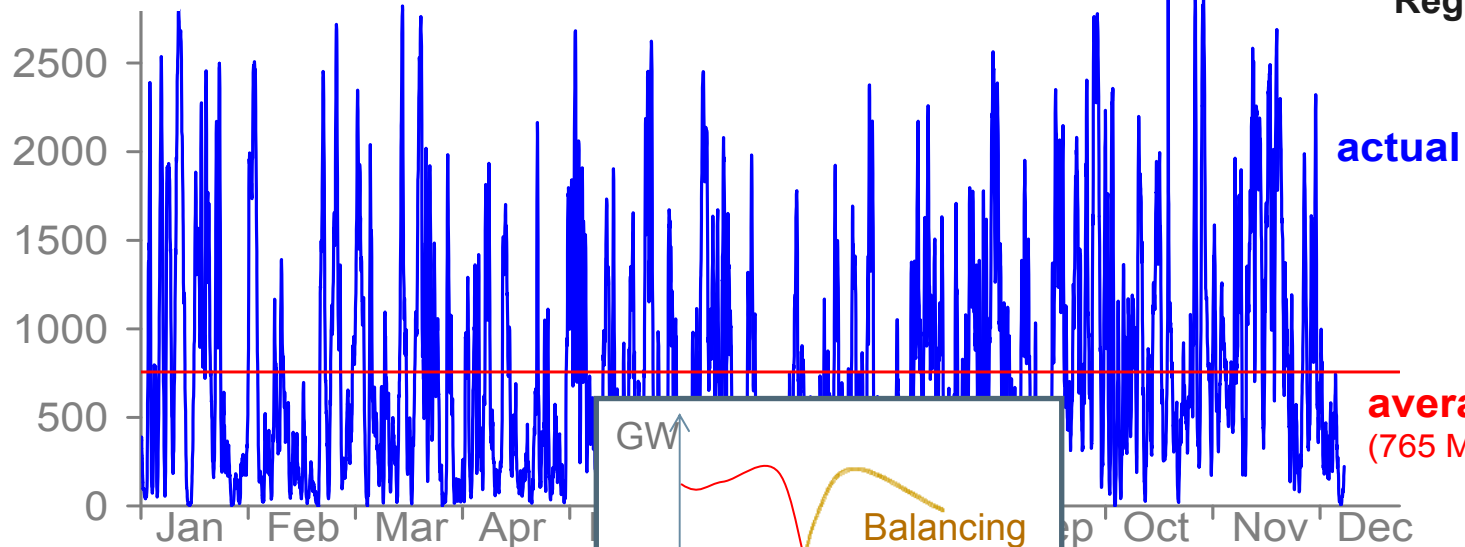
# Complement Intermittent Renewable Energy



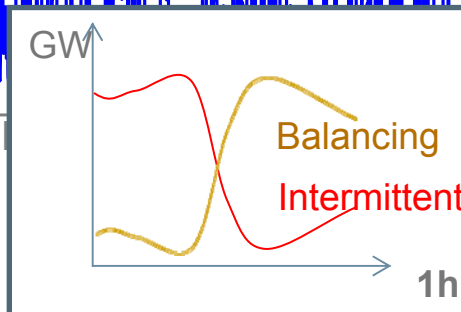
## Wind Production in Denmark in 2009



### Time Shift



### Regulation



### Ramp Rate

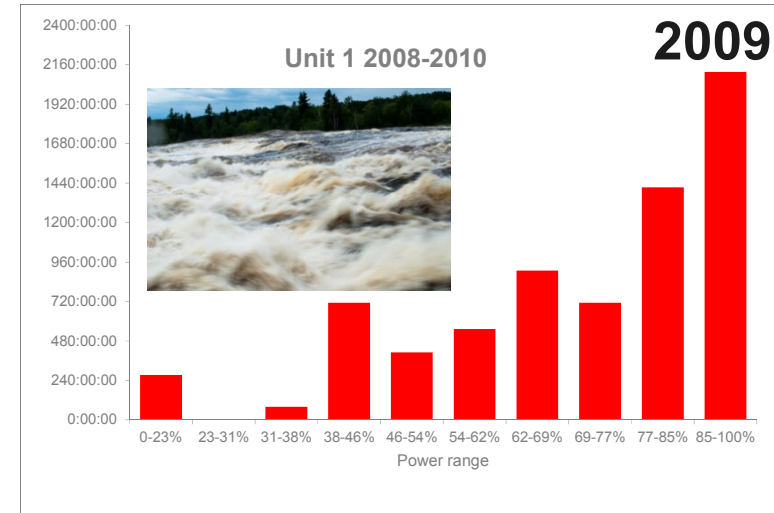
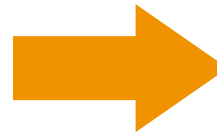
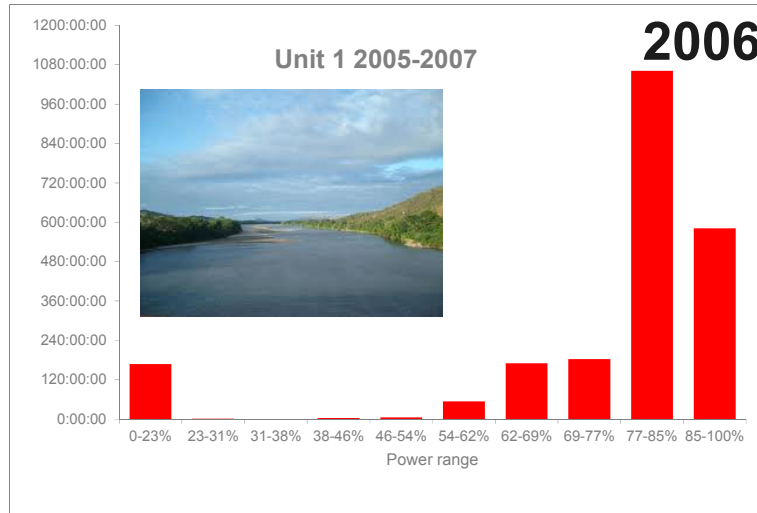
Source ENERGIENEK

- 
- Continuous improvement**
- In 40 years, from 70 to 80% cycle efficiency
  - Availability, Reliability, Cycling
- 

- More challenging sites**
- Very High or Very Low Head (<50m & >800m)
  - Head range increase
  - Underground reservoir
  - Sea water operation
- 

- Flexibility**
- Variable Speed offering
  - Power range increase in turbine mode
  - Reaction time reduction
-

# Future in PSP



**Flexibility**

Power operating range  
Transition time

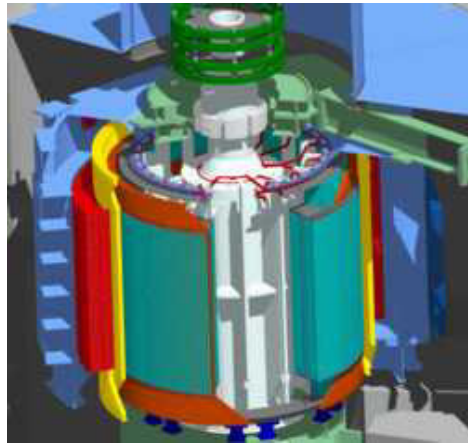
**Reliability**

Condition monitoring  
Fatigue analysis

**Performance**

Round trip efficiency  
Cycling

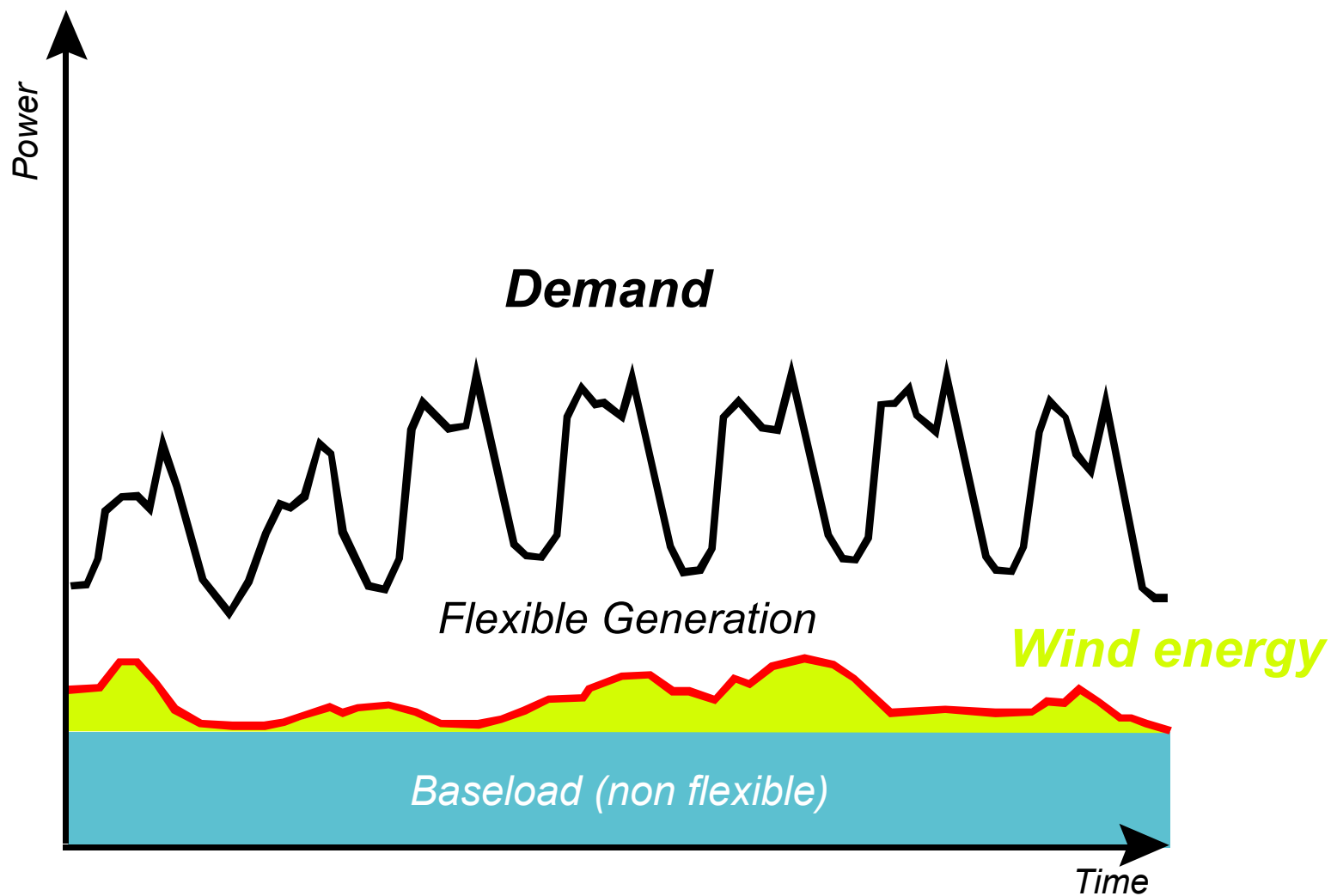
## Double Fed Asynchronous Motor Generator

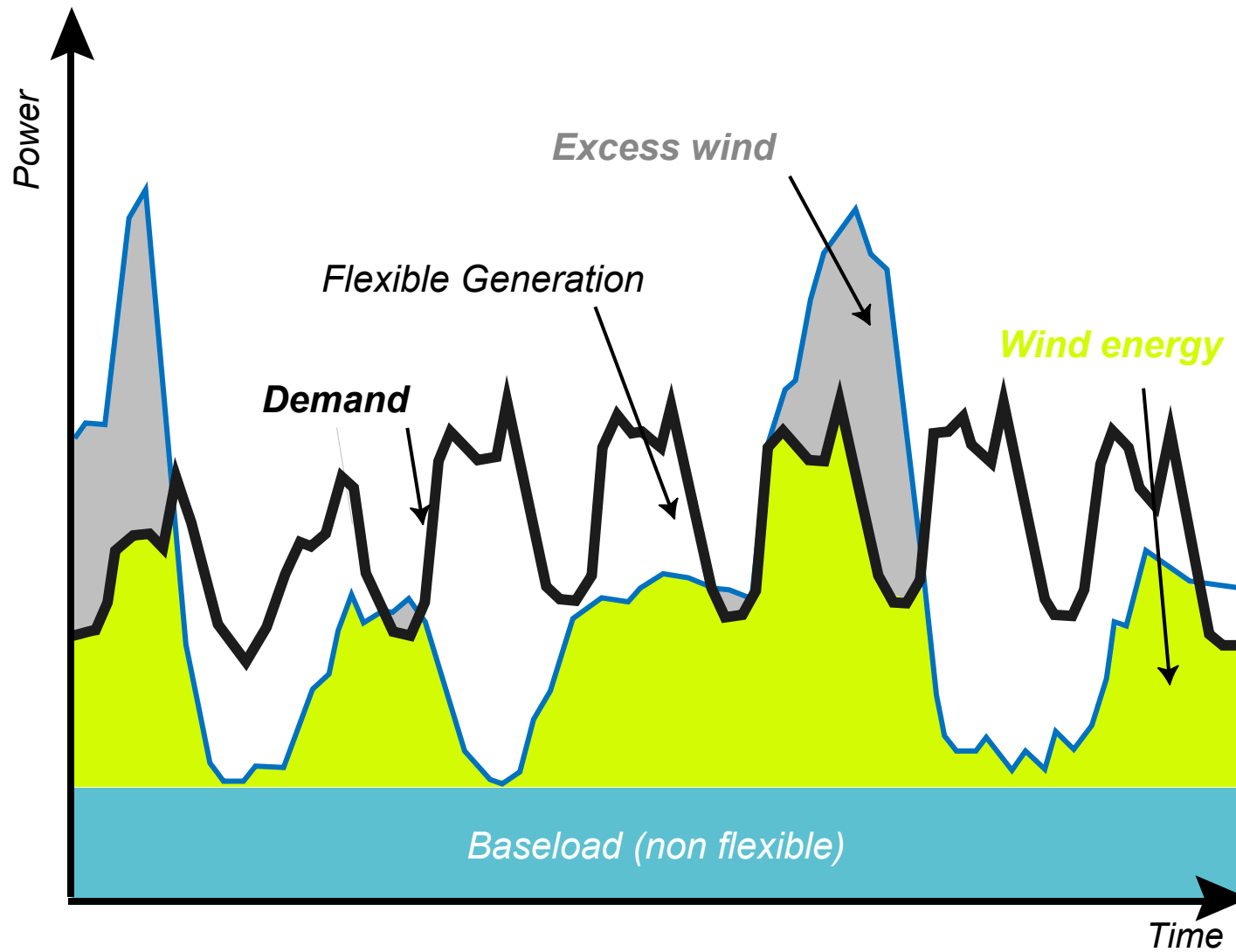


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### Advantages

- Adjustable pumping power
  - Compatible with larger head variation
  - Faster power adjustment
  - Pump Turbine global efficiency (+ ~ 1%)
-

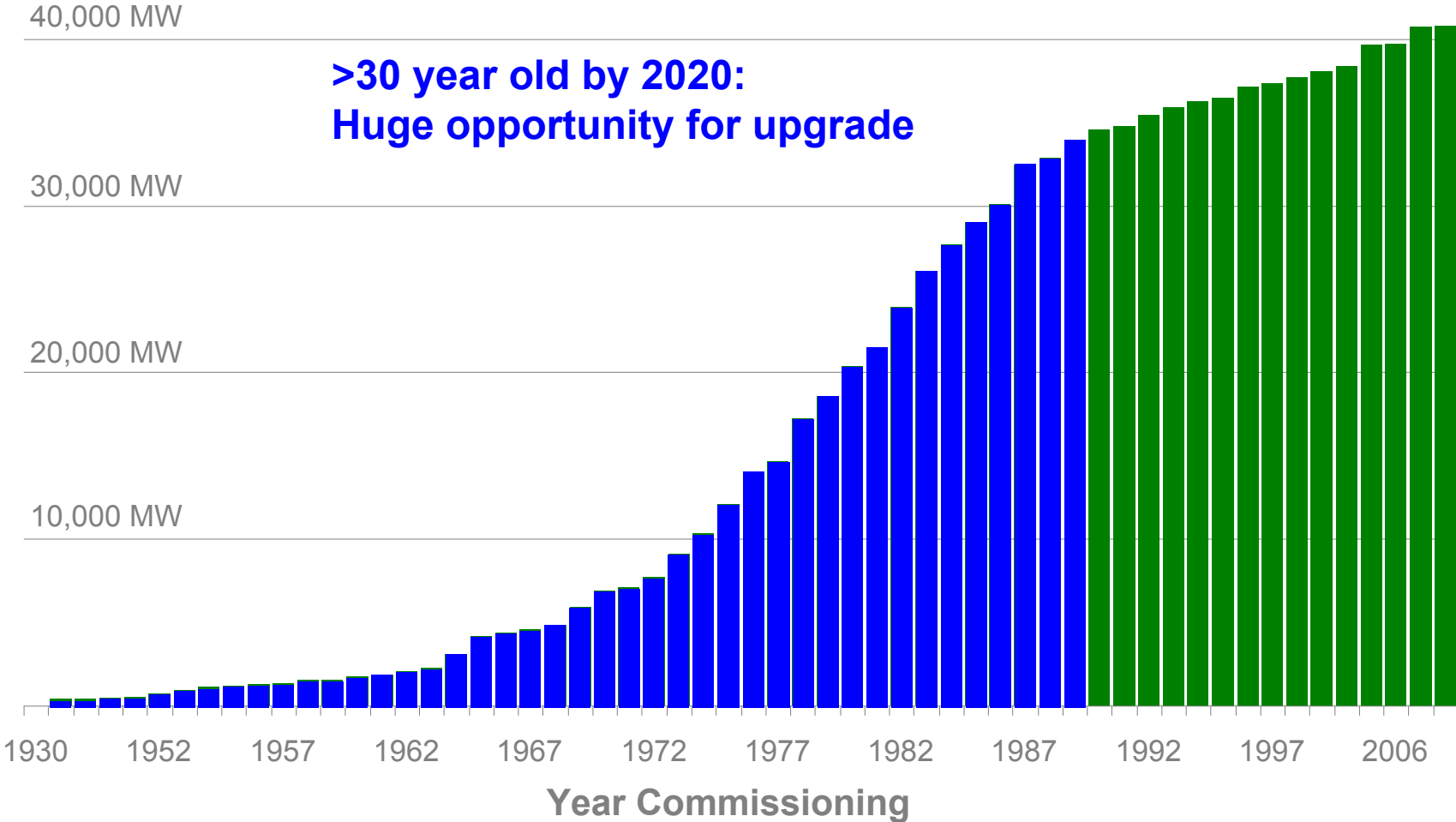




# European PSP installed Fleet



## Installed power





# Flexible Hydro Storage “Everywhere”

To enable

## Renewable Generation to remain Renewable

[www.power.alstom.com](http://www.power.alstom.com)

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