PUMPED STORAGE AND VARIABLE RENEWABLES INTEGRATION

MAIN TECHNOLOGIES AND APPLICATIONS OF PUMPED STORAGE

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Mexico City, Mexico

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AGENDA

What is pumped storage ?

What are the main drivers

Where to find pumped storage facilities

Forms of pumped storage

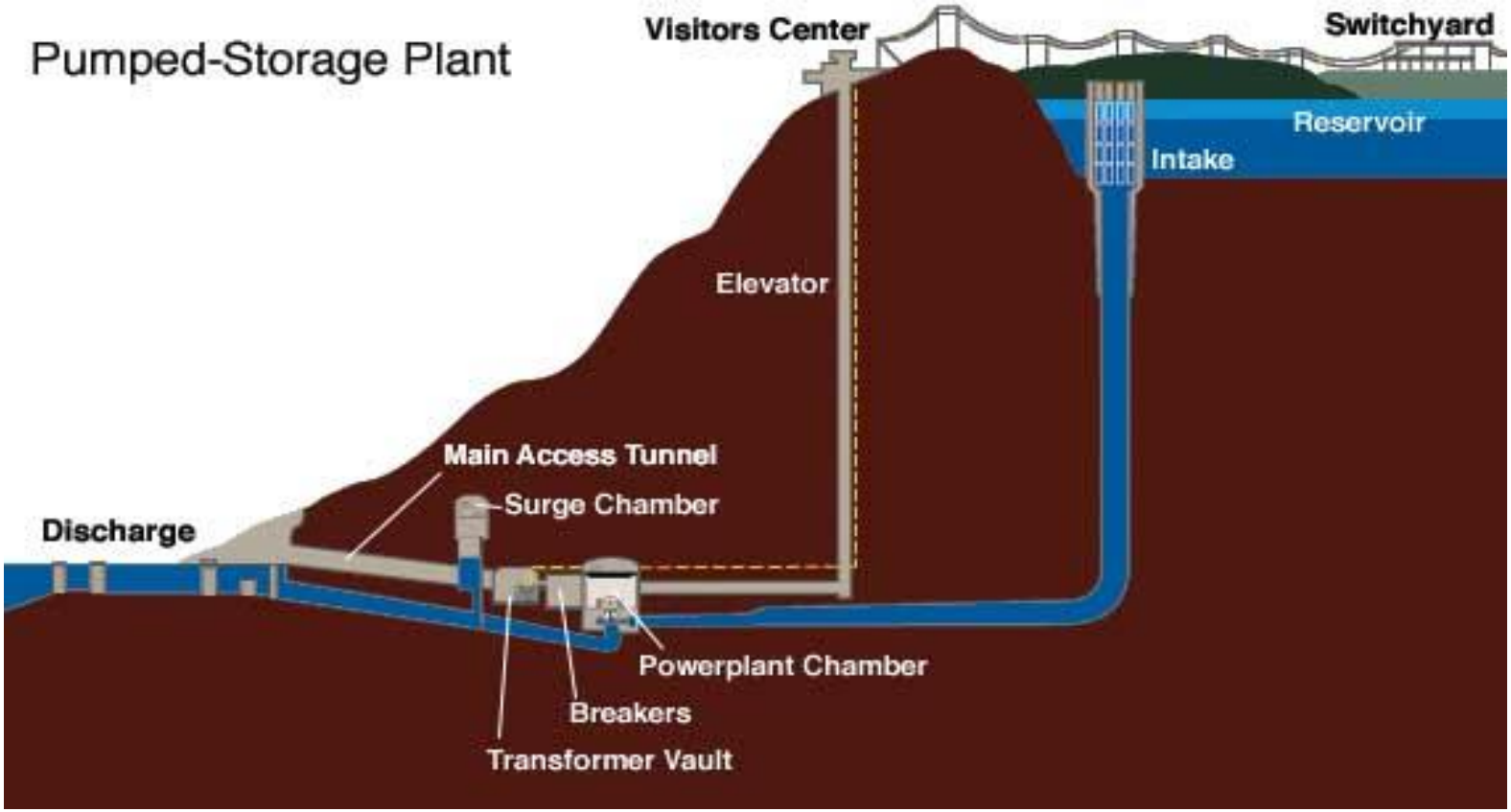
A wide range of mature technologies

Pumped storage and its competitors

Integrating wing and solar energy

Conclusion

WHAT IS PUMPED STORAGE ?



Raccoon Mountain Pumped Storage (USA)

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WHAT IS PUMPED STORAGE ?

Pumped storage has all the attributes of conventional hydropower :

- **Fast power control** to meet load variations
- Sufficient **power reserves** to balance grid
- Guaranteed **power availability** for defined time frames
- Sufficient and efficient **storage**
- **Blackstart** capacity on system interruption
- Electrical **frequency** and **voltage control**
- Effective and efficient **recovery of surplus** from RES and thermal

WHAT ARE THE DRIVERS

Historic Drivers:

Pumped storage was used in conjunction with large base loaded generation to store energy in periods of low demand for use in period of high demand; thought of as a **generation resource**

Today's Drivers:

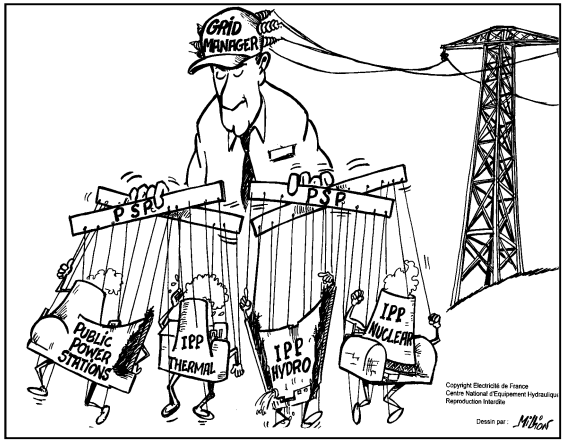
Pumped storage looks more like a **transmission resource** as it integrates new renewable energy sources like wind and solar into the grid

Pumped storage complements the **intermittent** nature of renewables, firming up resources to enable reliable grid operation

Utility systems with the greatest penetration level of **wind** have the greatest need

Pumped storage supports **reduction of greenhouse gas emissions** from the elimination of fossil peaking resources

Pumped storage is an established, **proven** and widely deployed bulk energy storage alternative



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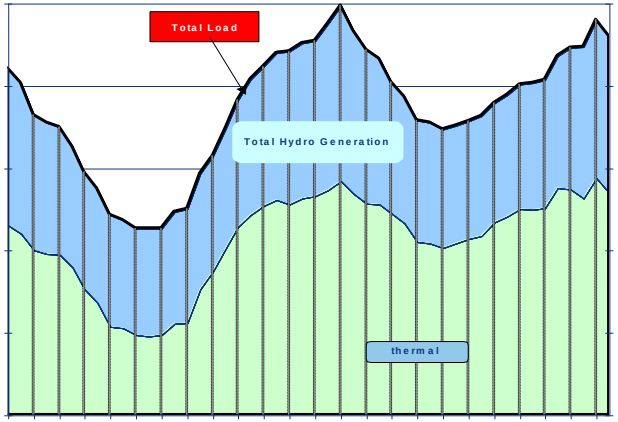
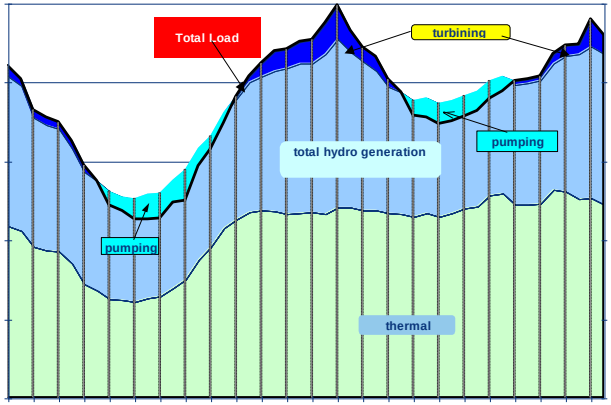
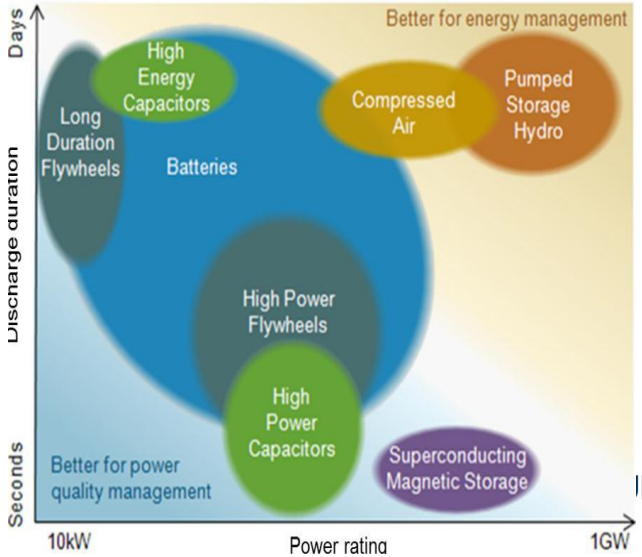
BENEFITS OF PUMPED STORAGE

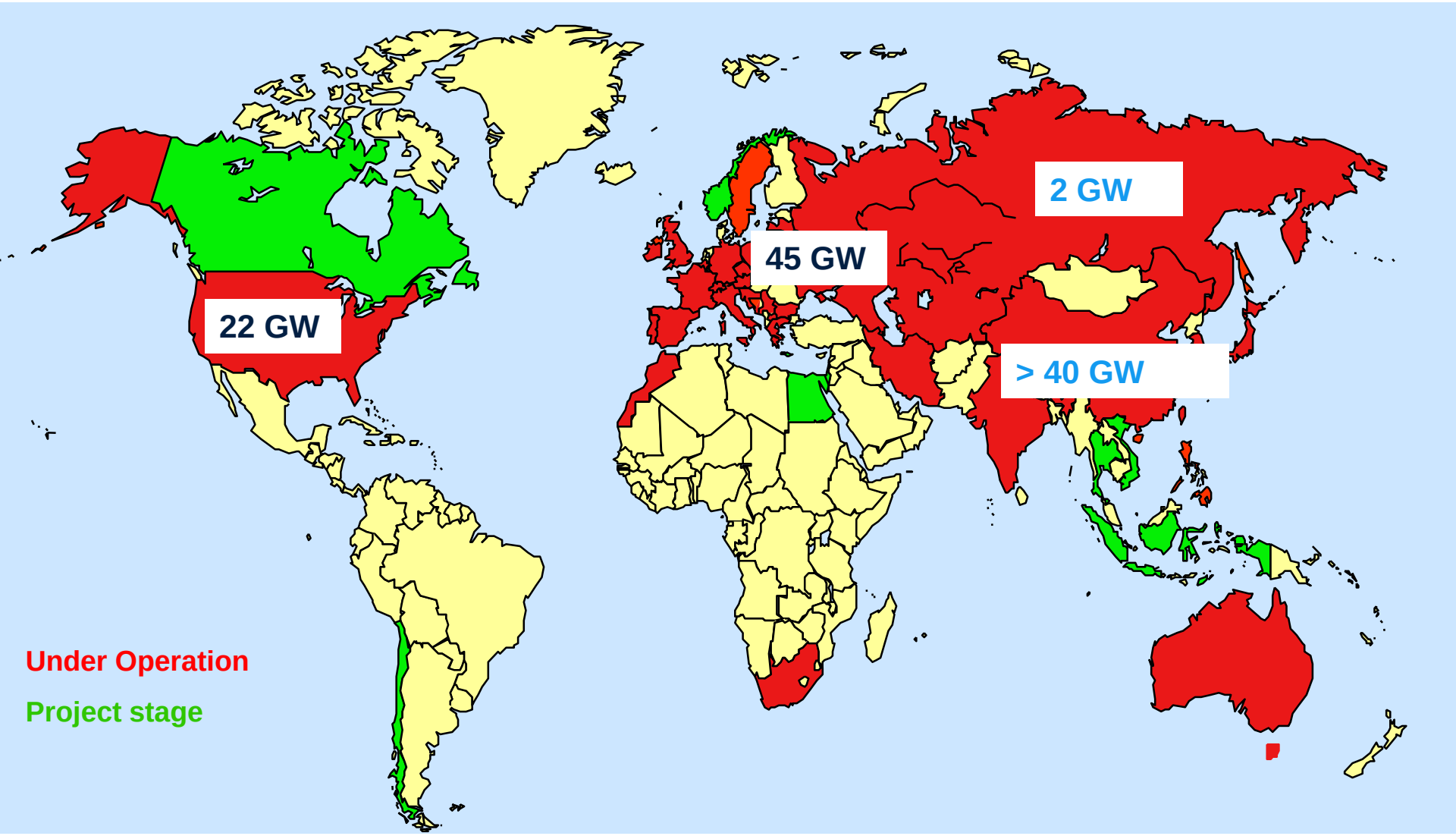
- Provides off peak to peak energy transfer
- Improves the flexibility and reliability of electricity supply by providing fast response to peak electric grid demands
- Increases the efficiency of existing power plants and transmission facilities
- Is an excellent supplier of ancillary services to provide grid stability
- Integrates renewables intermittent energy into the system
- Can be developed as extension of existing facilities
- Is usually considered as friendly to the environment







WHERE TO FIND PUMPED STORAGE FACILITIES



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FORMS OF PUMPED STORAGE PLANTS

Depending on the volume of the smaller reservoir (upper or lower), there are :

- « Daily » PSPs (pumping is required after a few hours of generation)
- « Weekly » PSPs (generation can last 20 to 40 hours without pumping)

Depending on the inflow into the reservoirs, PSPs can be :

- « pure » PSPs, when there is no significant inflow. Pure PSP are very flexible and predictable as, most of the time, operation of the reservoirs is free of restraints resulting from other water uses
- « mixed » PSPs, when their operation must take into account inflows into either the upper or lower reservoir.
- In both cases large room for optimization.

FORMS OF PUMPED STORAGE PLANTS

Okinawa PSP - Japan

Revin PSP - France

Kopswerke PSP - Austria

Tehri PSP Project - India

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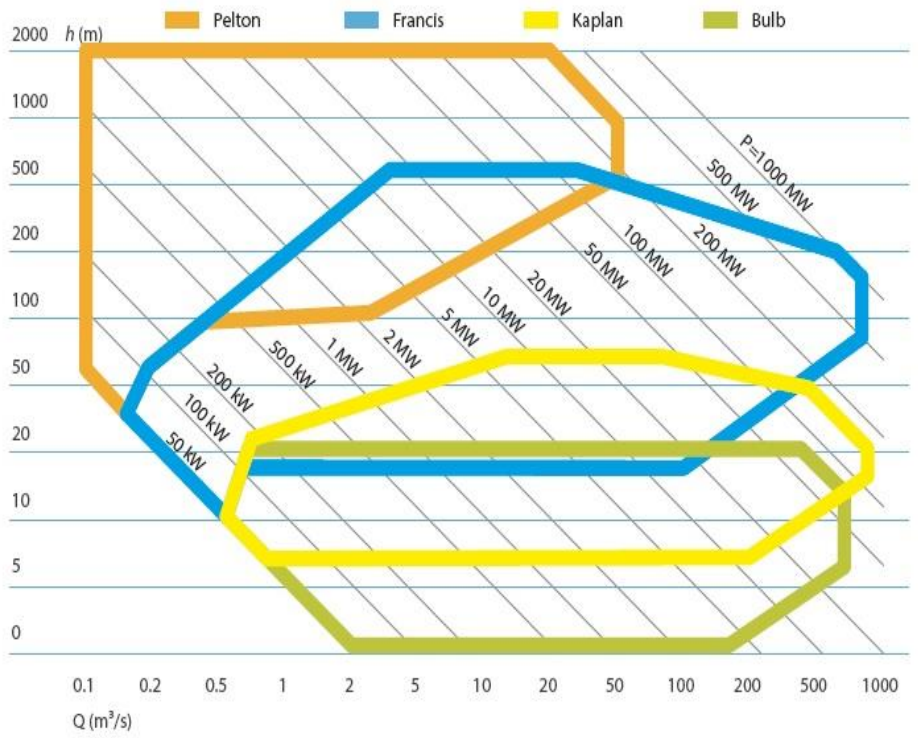
A WIDE RANGE OF MATURE TECHNOLOGIES

- Reversible pump-turbines without variable speed equipment
- Reversible pump-turbines with adjustable speed
- Ternary block
- Totally separated machines



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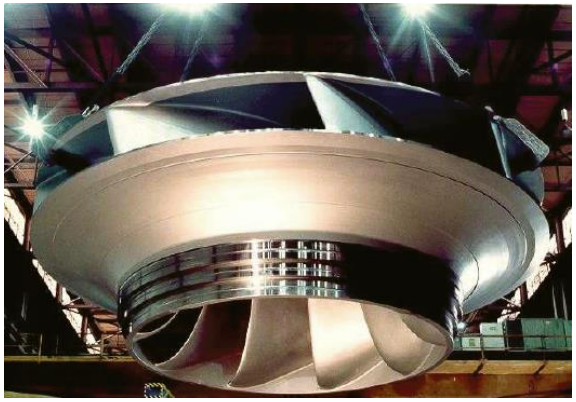
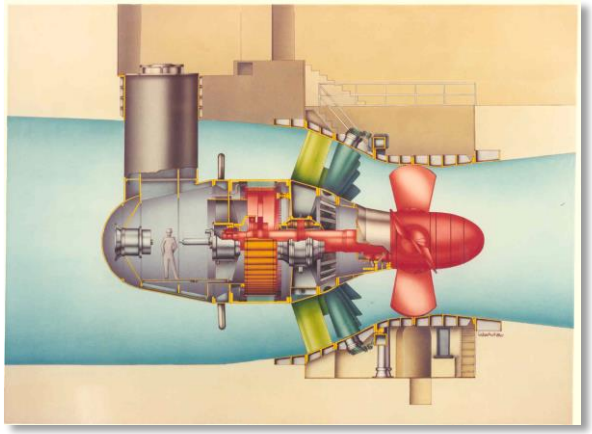
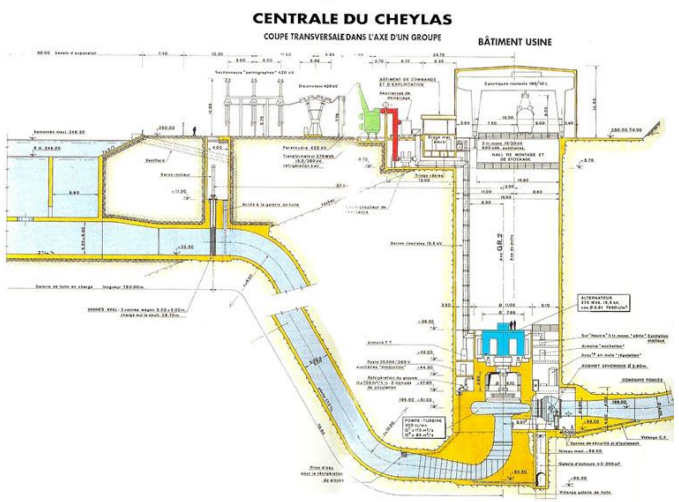
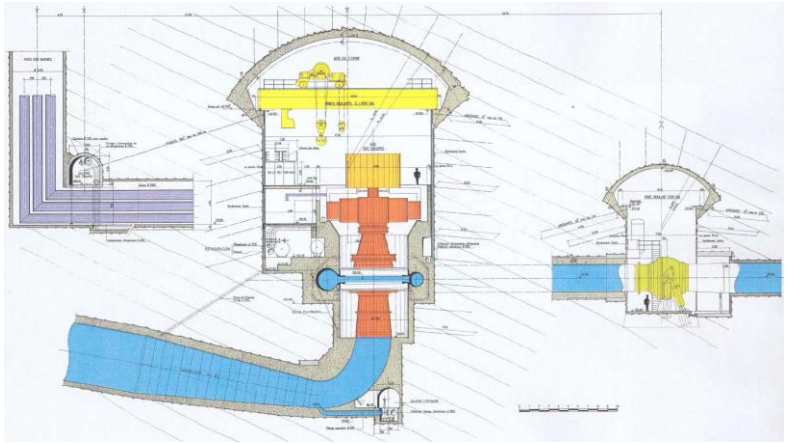






Le Cheylas (France)



La Coche (France)

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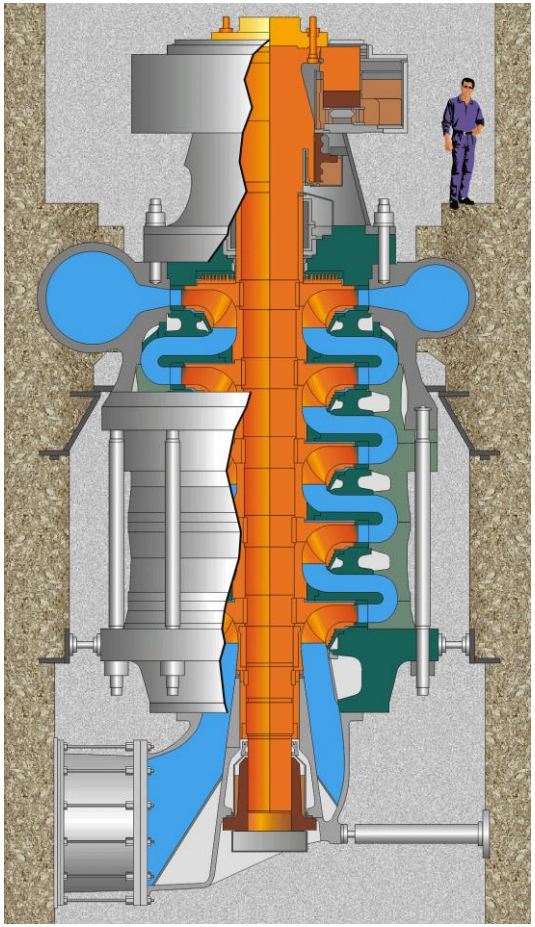
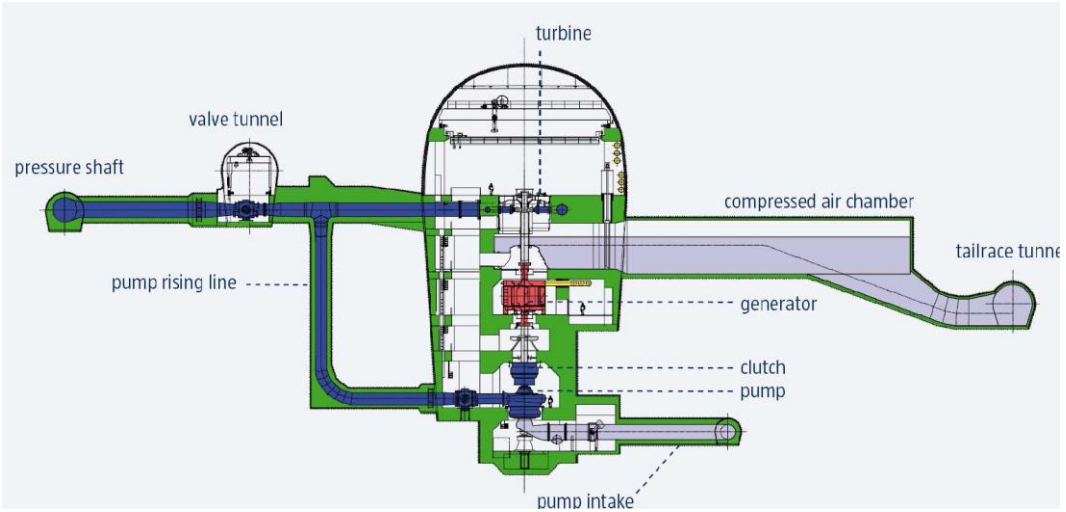
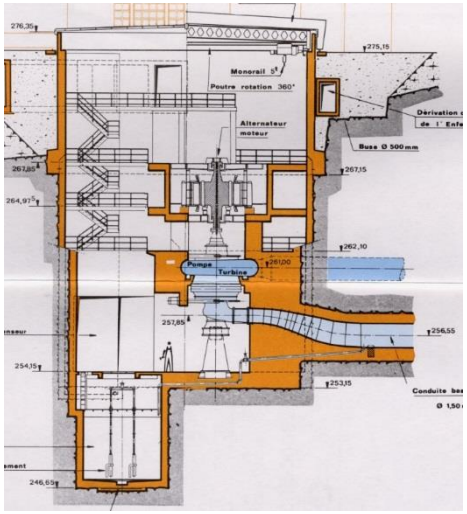


Grand Maison (France)



Kopswerke (Austria)



Yangyang (Korea)

MATURE BUT STILL EVOLVING
An example with the turbine type selection

Single speed turbine	Variable speed turbine
Proven technology with multiple suppliers	Wide head range operation.
Lower equipment cost by ~ 30%.	Flatter and higher generating performance curve.
Smaller powerhouse size.	Regulation in pumping cycle +/-20% in power.
Lower O&M costs.	Wider generating operating range.
Shorter project schedule.	

PUMPED STORAGE AND ITS COMPETITORS

Competition with other possible options has to be considered, depending on the power system:

- Interconnection with other power system(s);
- Additional capacity at hydro power plants;
- Semi-base load power plants (where the peaking needs are for relatively long duration);
- Gas turbine (where the peaking needs are for a short duration);

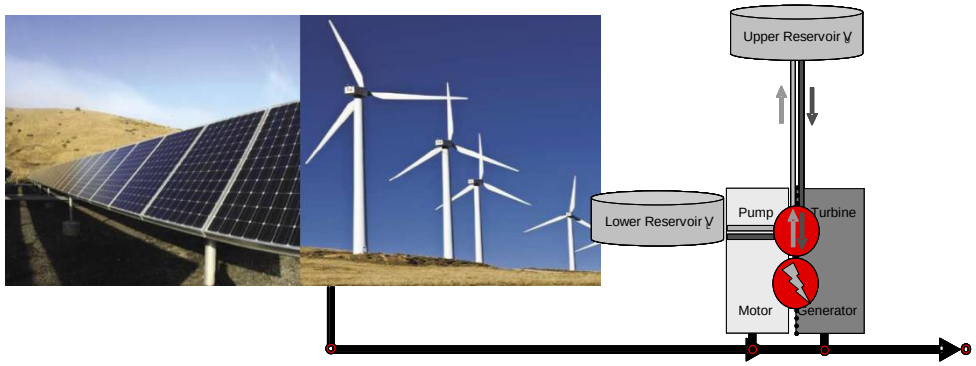
Planning for pumped storage requires detailed power system analysis

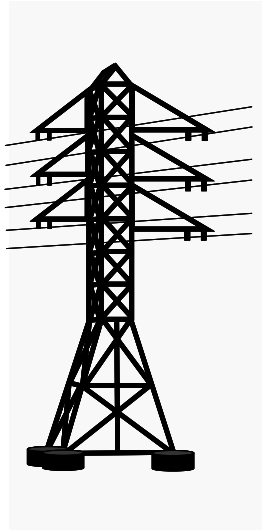
INTEGRATING WIND & SOLAR GENERATION

Characteristics of Wind & Solar energy:

- Intermittent and Variable
- Difficult to predict
- Cannot meet fluctuating demand
- No inertia

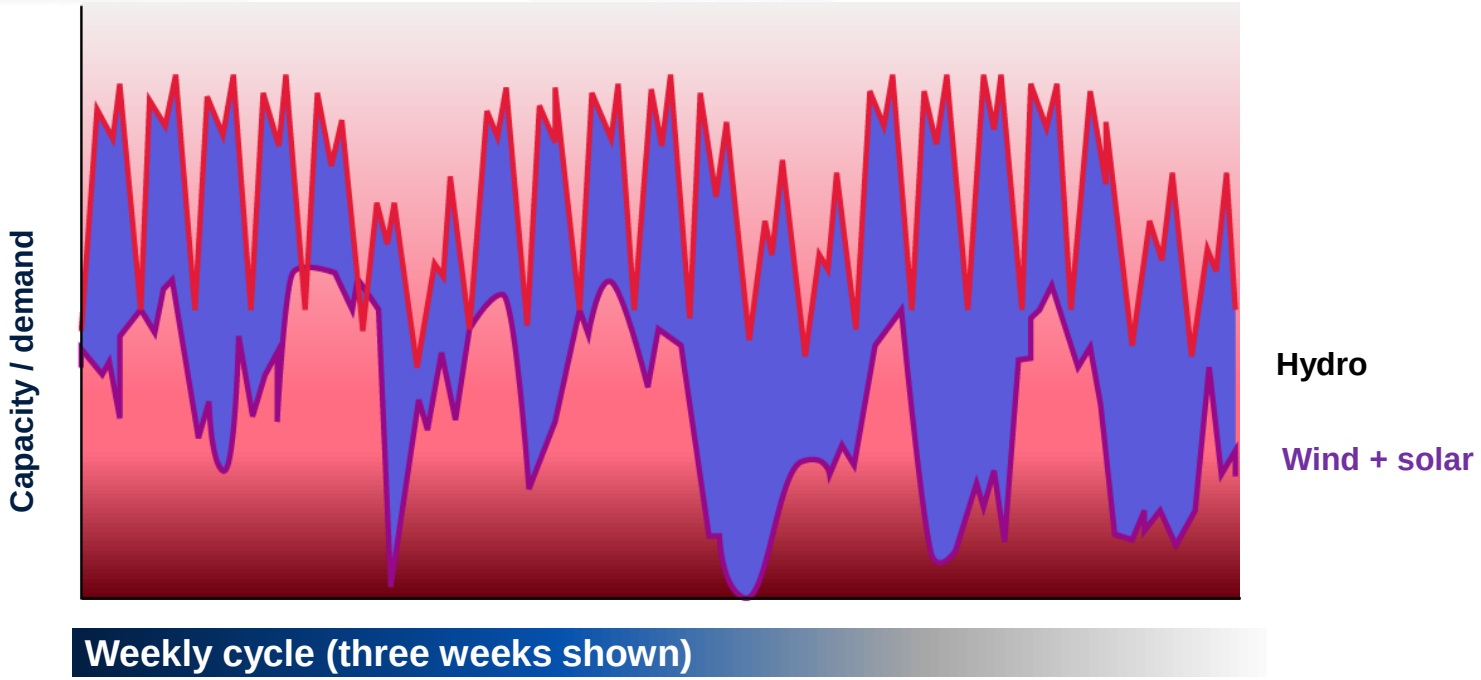
New and large electrical storage options are needed to compensate for fluctuating generation.





INTEGRATING WIND & SOLAR GENERATION

Hydropower + **Wind** + **Solar**



Schematic illustration

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CONCLUSION

The grid manager nowadays not only has to deal with traditional constraints to meet the demand at all times at least cost with good quality, he has to face the development of large amounts non dispatchable renewable power projects.

Pumped storage is an attractive way to solve those difficulties. They are flexible and reliable, their « fuel » is renewable and they can be used to consume excess energy during off-peak hours.

Competitors to pumped storage must be considered in the decision making process and it requires a detailed power system analysis.

Pumped storage offers a large room for optimization on a given potential site.

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