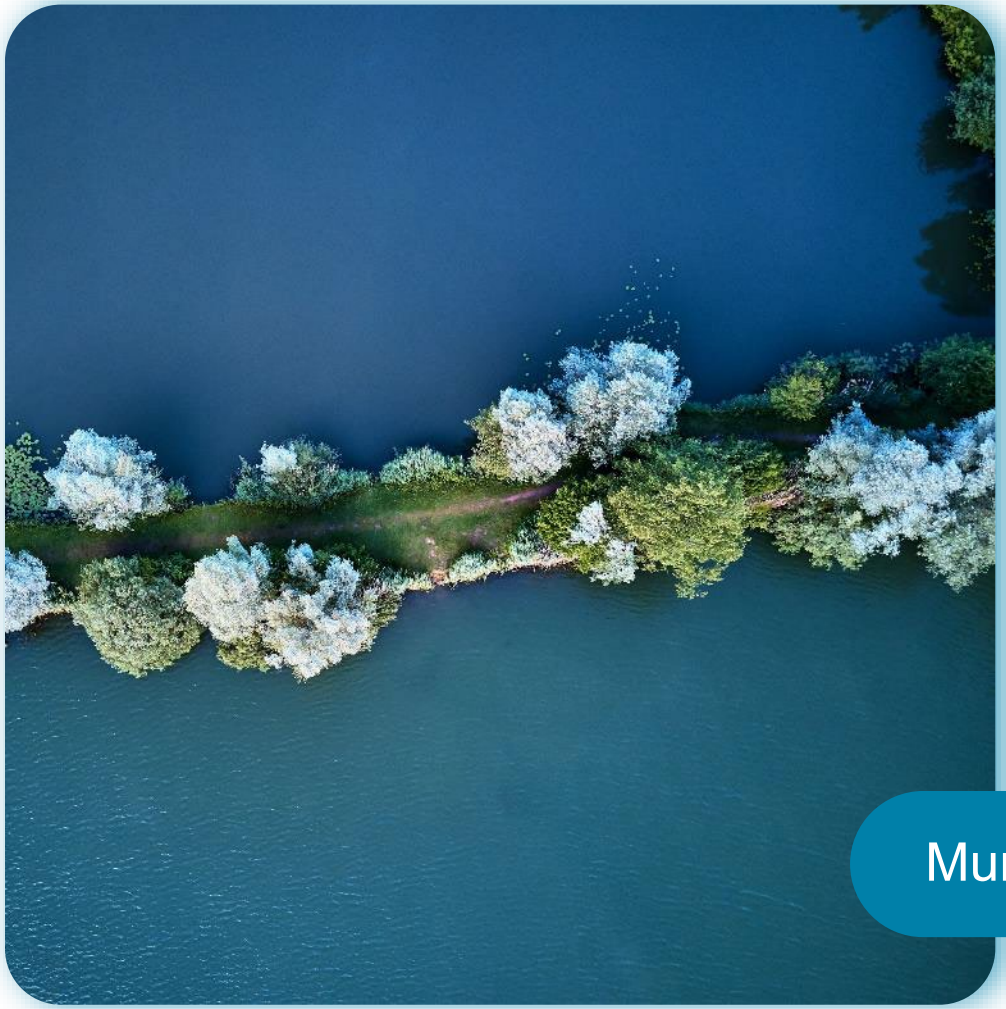


Renewable Energy

Engineering - Elsie WANG / Pui Fong HAN

May 2025

SCOR
The Art & Science of Risk

What is Renewable Energy?







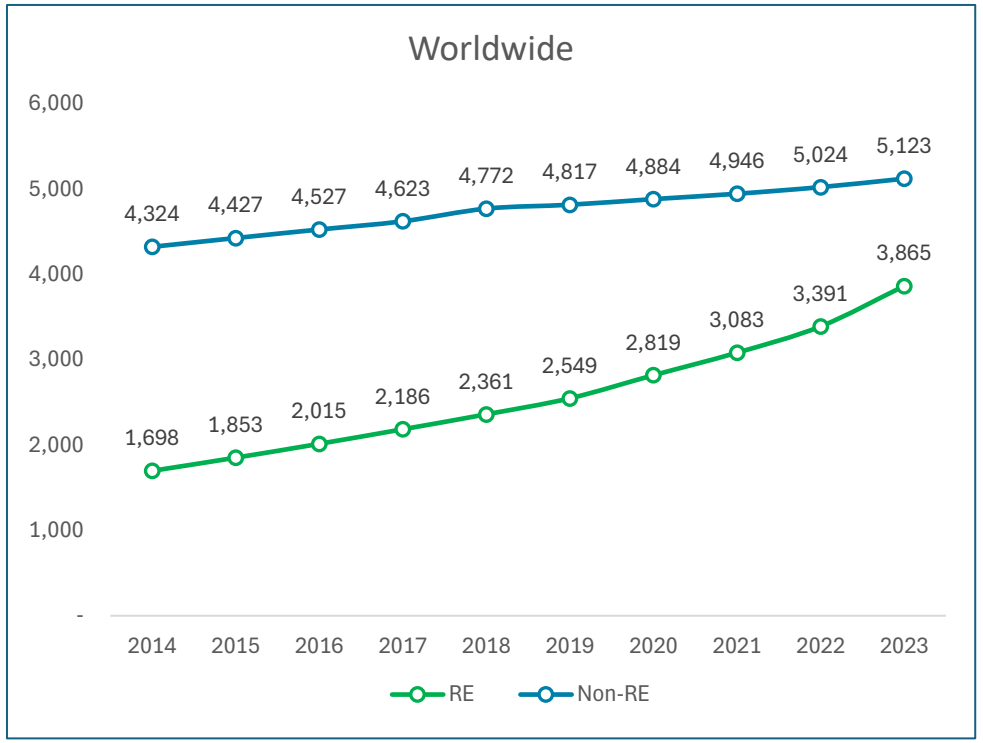


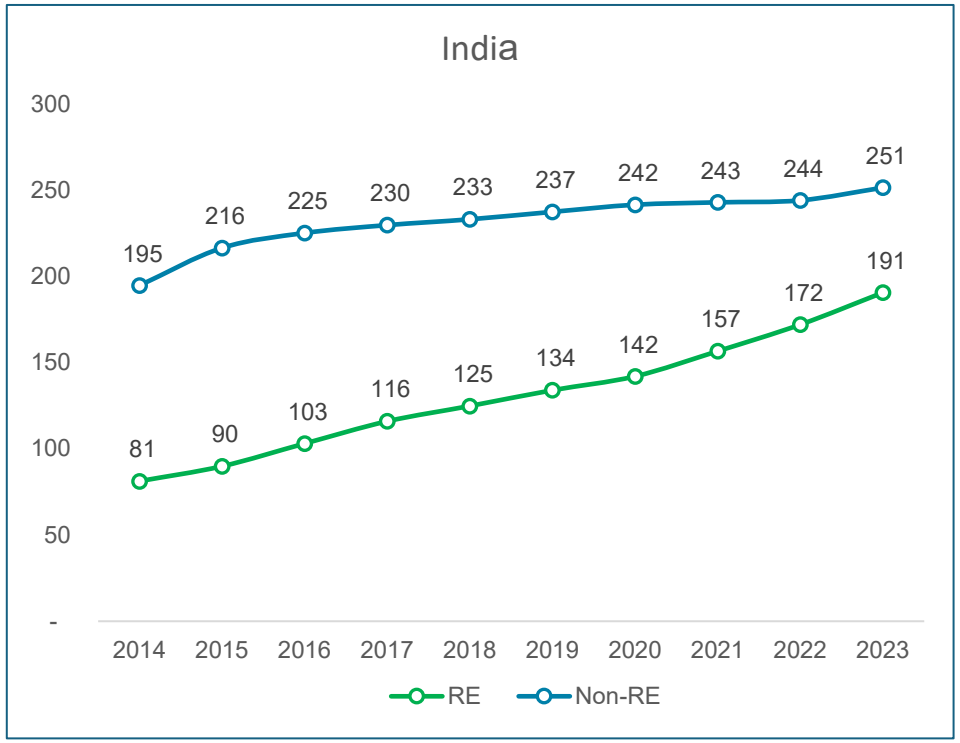


[Geothermal energy – Wikipedia]
[Exploring examples of wind energy | Sterling TT]
[Hydropower in India: Balancing global carbon benefits with local environmental costs]

SCOR The Art & Science of Risk

Renewable Energy
Installed Capacity

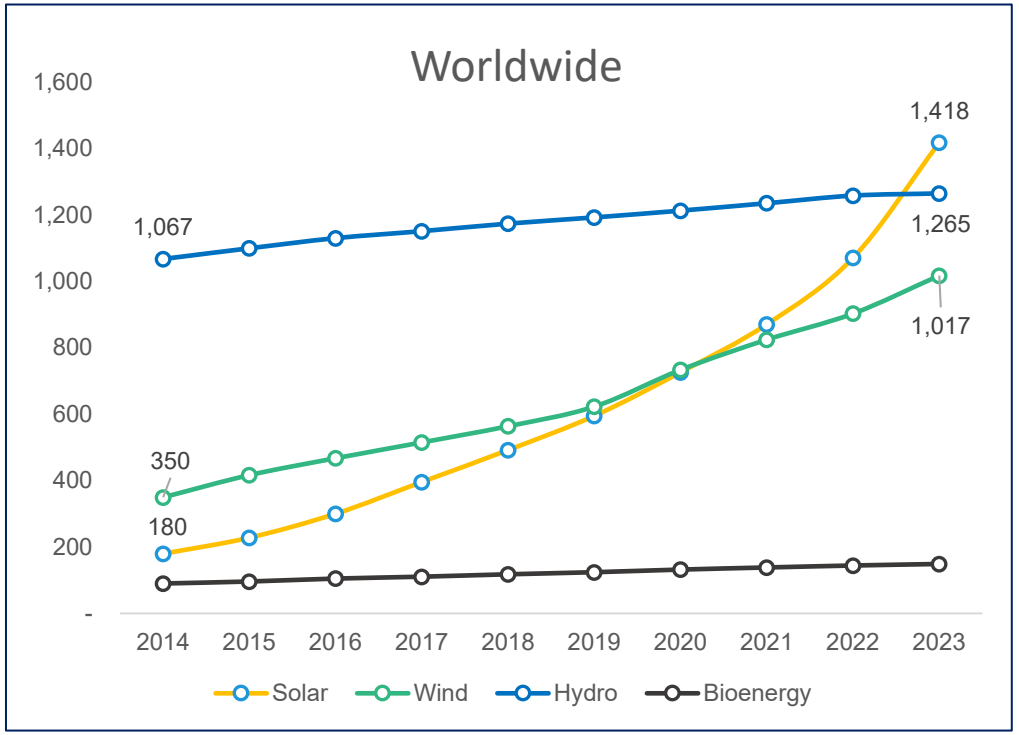


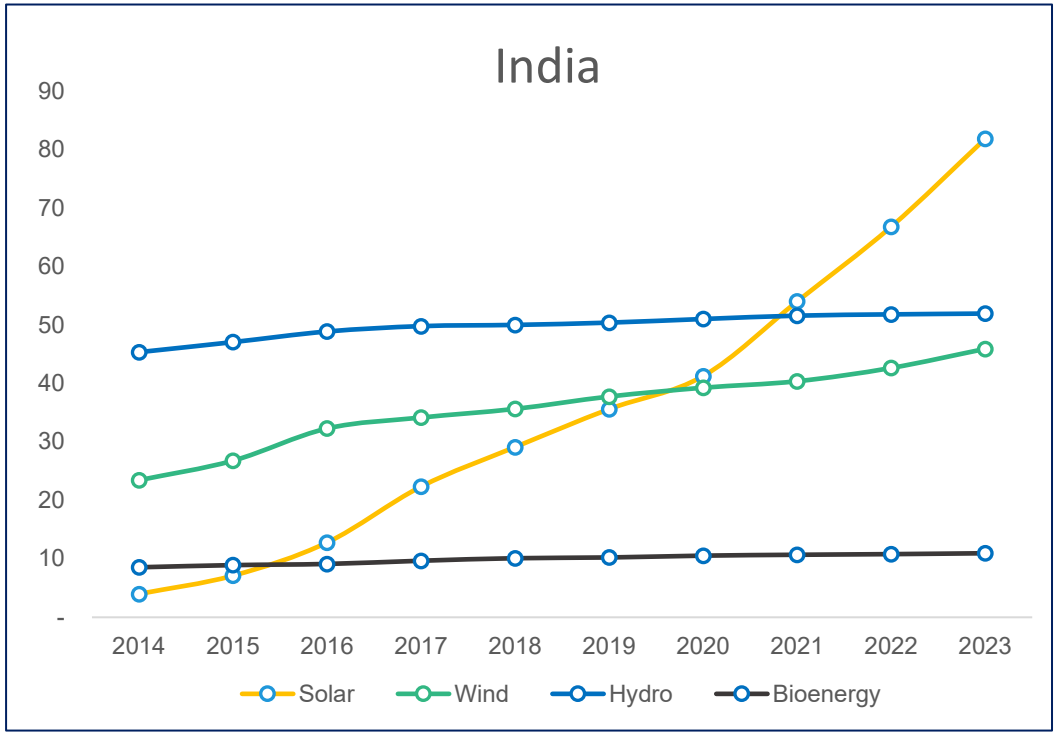


Source: Ministry of New and Renewable energy (MNRE) and Central Electricity Authority (CEA)

SCOR The Art & Science of Risk

Renewable Energy
Installed Renewable Energy Capacity

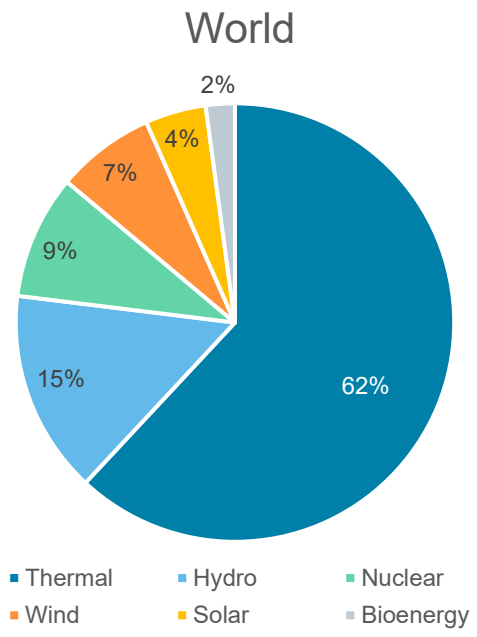


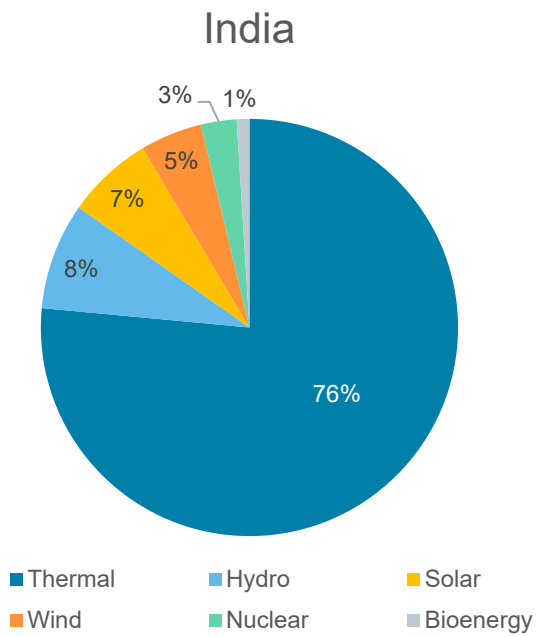


Source: Ministry of New and Renewable energy (MNRE)

SCOR The Art & Science of Risk

Renewable Energy
Energy Generation (On-grid)



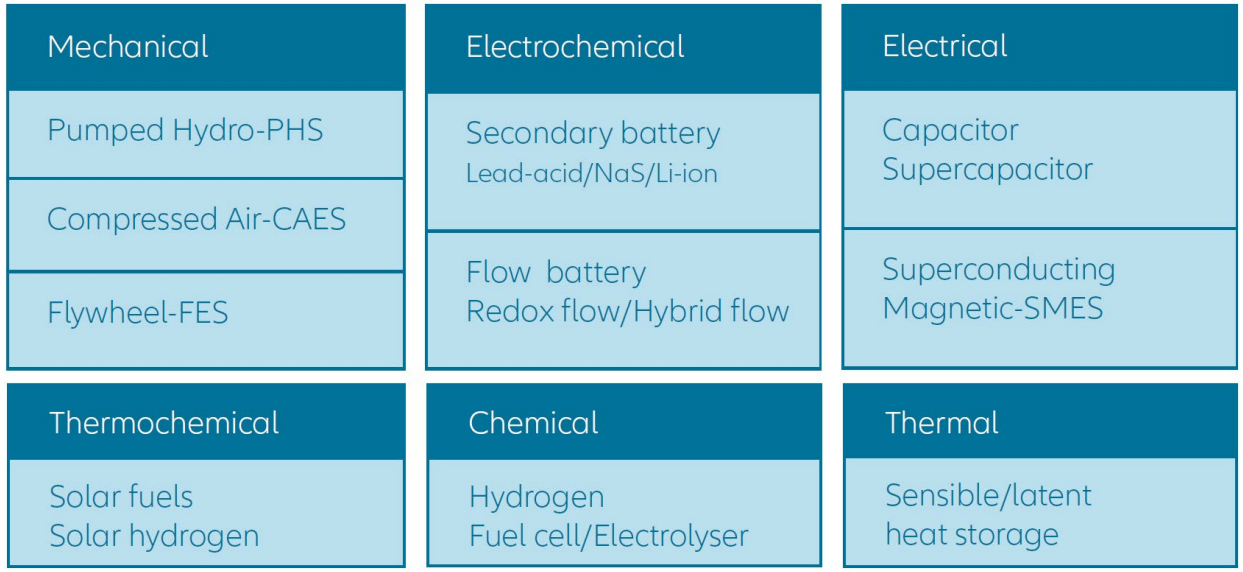


	World	India
Thermal	17,877	1,326
Hydro	4,330	144
Nuclear	2,640	48
Wind	2,098	83
Solar	1,294	116
Bioenergy	619	17
	28,859	1,734

SCOR
The Art & Science of Risk

Challenges of Renewable Energy

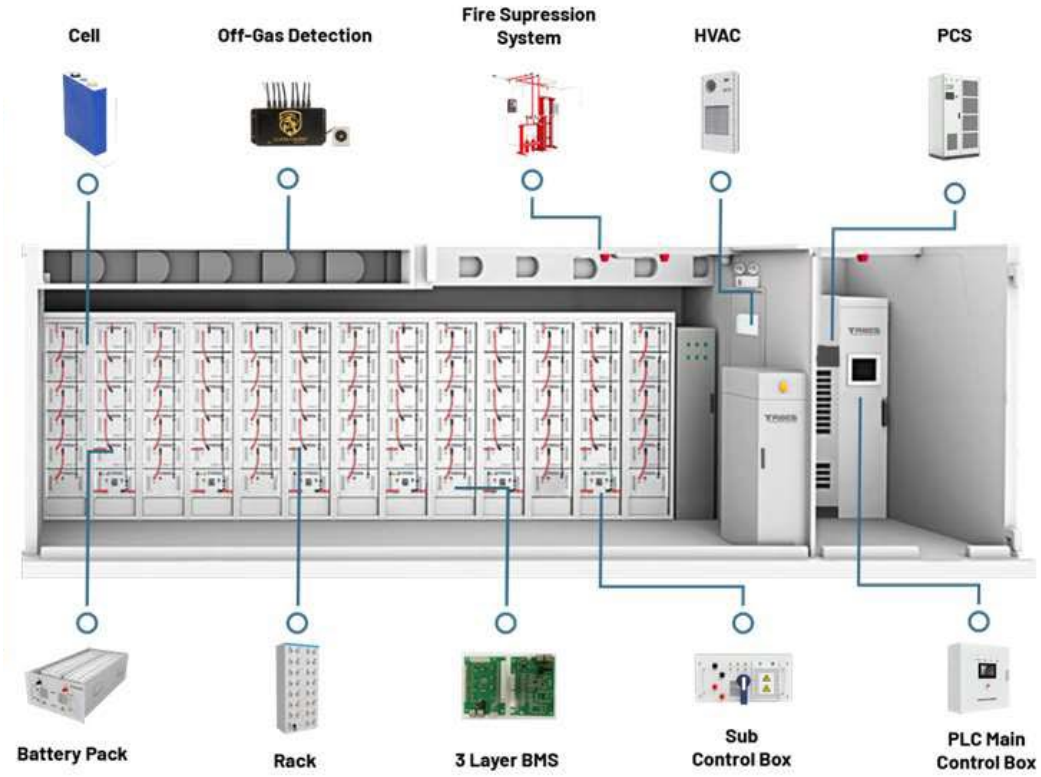
- Intermittency & Availability
- Grid Integration & Infrastructure
- High Initial Cost & Resources

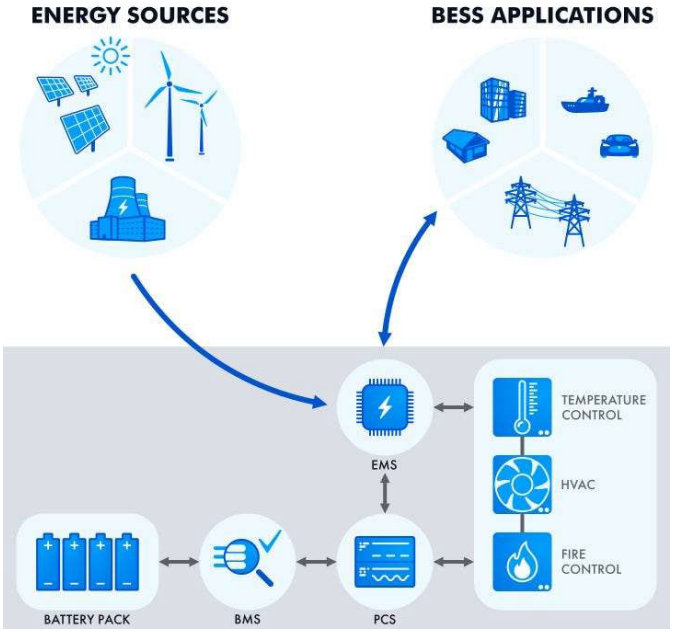


SCOR
The Art & Science of Risk

3. Battery Energy Storage System (BESS)

BESS
Components



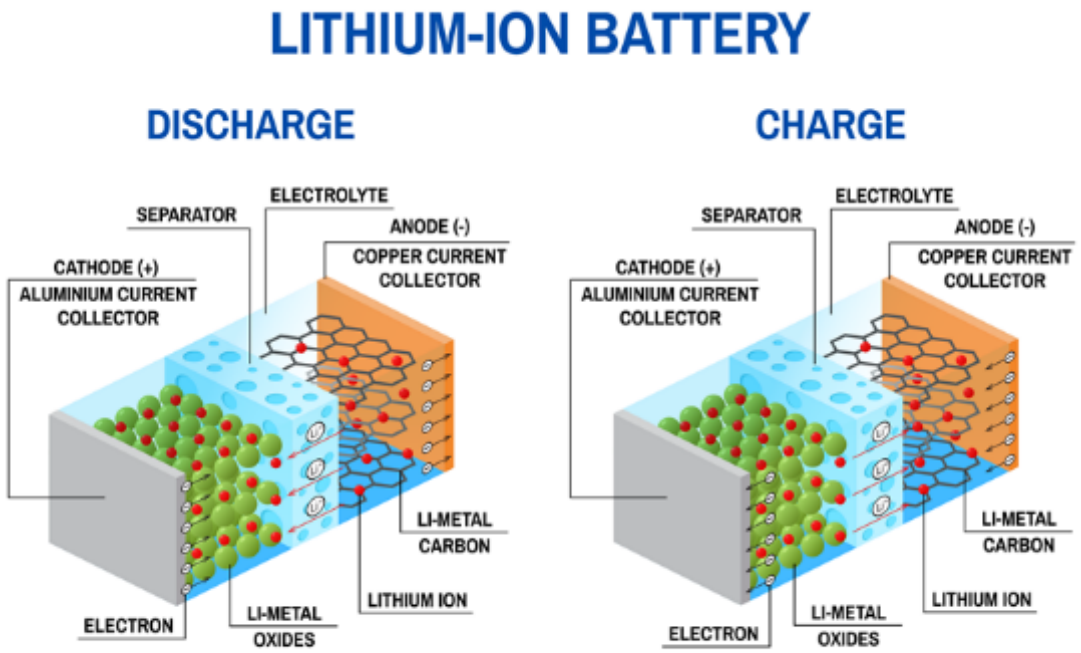


1. **Battery** - Energy storage
2. **Battery Management System (BMS)** - Ensures safe and optimal battery operation
3. **Power Conversion System (PCS)** - Converts power between DC (battery) and AC (grid) and controls energy flow
4. **Energy Management System (EMS)** - The "brain" of the BESS, optimizing energy dispatch based on algorithms
5. **Auxiliary Equipment** - Temperature/Fire Control

Source: Didier Schütz

SCOR The Art & Science of Risk

BESS
Lithium-ion Chemistry



- Most common due to high energy density, efficiency (~90-95%), and declining costs.
- Chemistry:
  - ✓ LFP (Lithium Iron Phosphate)
  - ✓ NMC (Nickel Manganese Cobalt)
  - ✓ NCA (Nickel Cobalt Aluminium)
- Hazard:
  - ✓ Thermal Runaway – Fire / Explosion

How to choose the right lithium-ion battery? - Ruchira Green Earth Blog

SCOR The Art & Science of Risk

BESS
Components

Prismatic battery cell

Pros:
- high strength
- small internal resistance
- long life
- high space utilization

Cons:
- Difficult to unify the production process
- difficult to dissipate heat

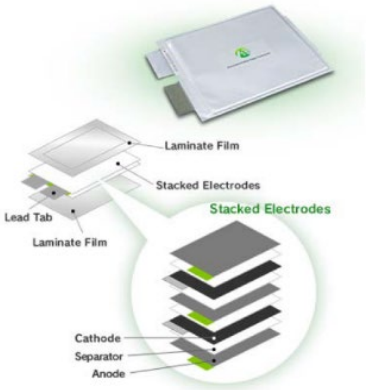
Prismatic cell

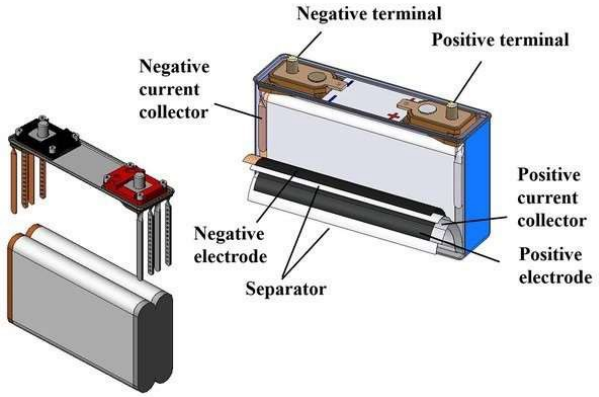


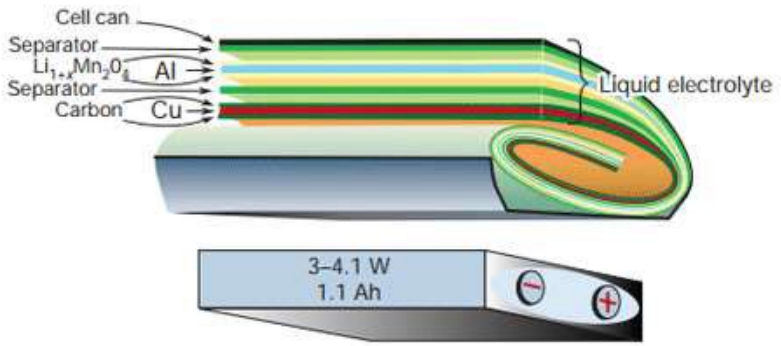
Cylindrical cell



Pouch cell

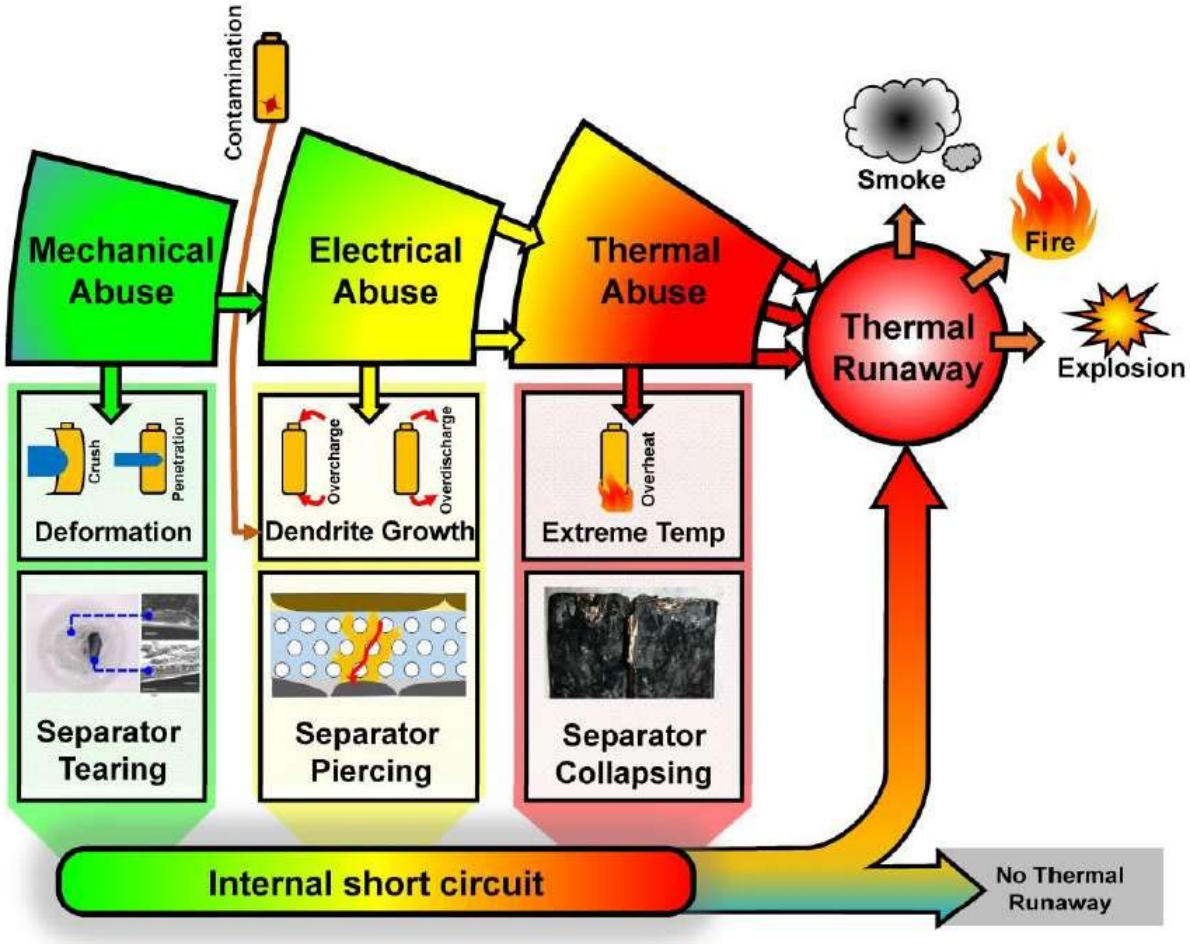






SCOR
The Art & Science of Risk

BESS
Thermal Runaway



Source: Didier Schütz

SCOR The Art & Science of Risk

BESS
Risk Exposure

Thermal Runaway - Damaged battery / Overcharging/short circuits / Poor thermal management

Electrical Hazards - Electric shock / Arc flashes / Incorrect wiring

Chemical Leaks - Electrolyte leaks / Toxic gas release

Mechanical Failure - Poor Workmenship **/** Crush / Falls

Structural Collapses - Rack/cabinet collapse / Foundation failures

SCOR
The Art & Science of Risk

BESS
Loss Experience

2025 - Fire - Moss Landing, US

Dramatic fire breakout that destroyed most of a 300MW array

Cause: Under investigation

Loss: USD 400 – 500M



[Fire at world's largest battery facility is a clean energy setback | New Scientist]
[Moss Landing Battery Fire: Fallout & Repercussions]

SCOR The Art & Science of Risk

BESS
Loss Experience – Testing & Commissioning



2021 - Fire & Explosion
Moorabool, Australia

The fire and Explosion broke out during testing of a Tesla megapack.

Cause: Cooling system failure

Crews battle Tesla battery fire at Moorabool, near Geelong - ABC News

BESS
Loss Experience – Testing & Commissioning

2023 - Fire - Bouldercombe, Australia

A fire has taken place as it reached the final stages of its commissioning phase.

Cause: fault on the AC side, propagated to battery modules


type involving Tesla Megapacks. Image: Country Fire Authority.

SCOR
The Art & Science of Risk

BESS
Loss Experience – Nat Cat

2022 - Hurricane Ian - Manatee Energy Storage Center, USA

Severely damaged by flooding, requiring full replacement, uninstalled container were blown and distorted.

2021 - Heavy Rainfall / Flood - Zhengzhou, China

Heavy rainfall (622mm in day) leading to Flooding to some of the containers causing short-circuit, delayed construction work for 3 month

Loss: EUR 5 - 7M

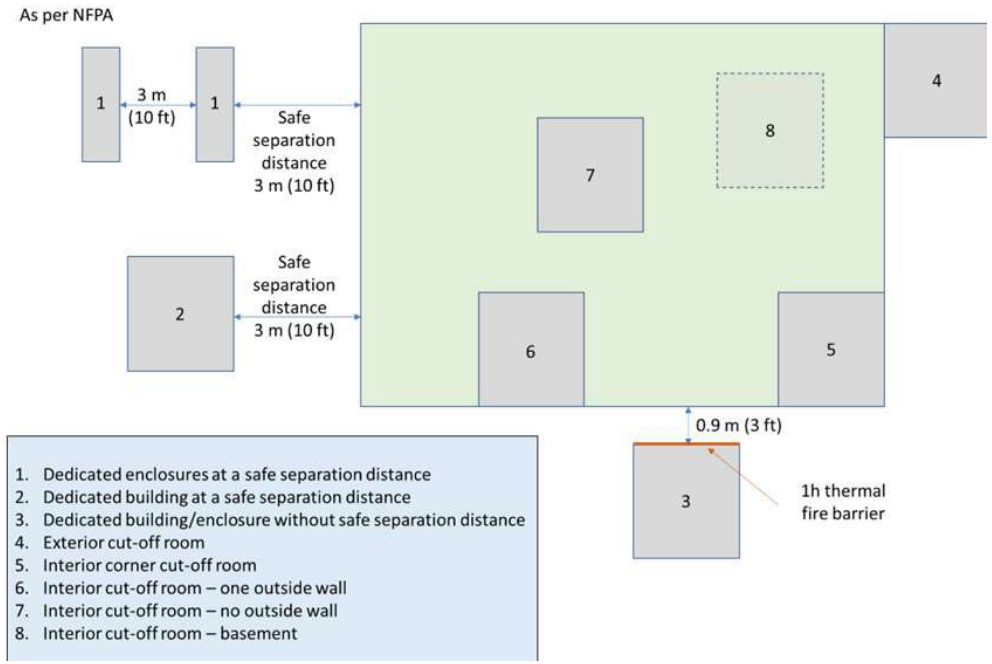
SCOR
The Art & Science of Risk

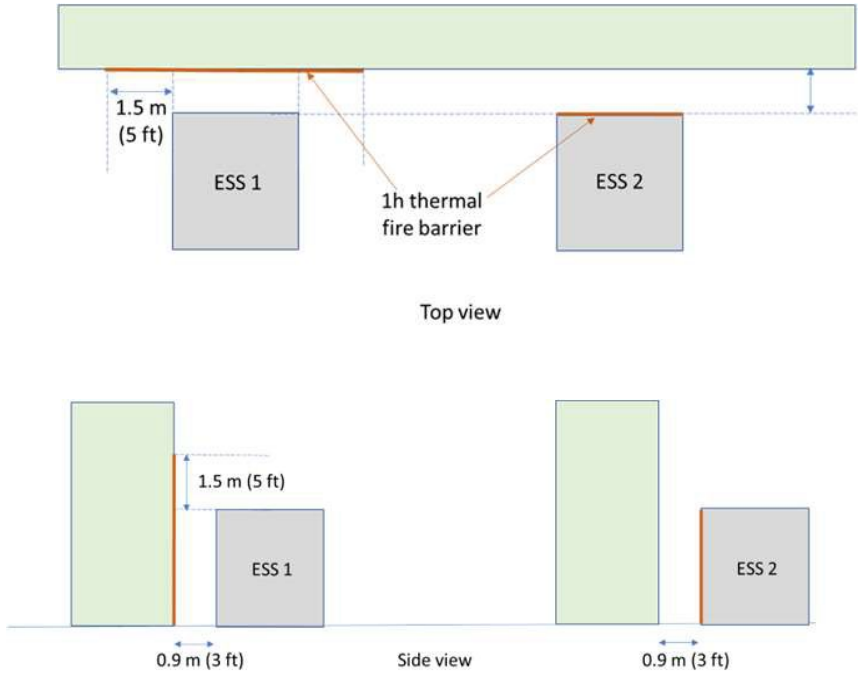
BESS
Risk Management

Classification	Standards & Codes
Manufacturing of batteries, ESS	• **UL 1642**: Lithium batteries • **UL 1973**: batteries for use in stationary, vehicle auxiliary power and light rail • **UL 9540**: Energy storage system and equipment
Construction, installation of ESS	• **NFPA 70E**: Standard for Electrical Safety in the Workplace • **NFPA 855**: Standards for the installation of stationary energy storage systems • **IFC**: the international fire code
Additional testing for BESS	• **UL 9540A**: Test method for evaluating thermal runaway fire propagation in battery energy storage systems

SCOR
The Art & Science of Risk

BESS
Fire Protection – NFPA 855





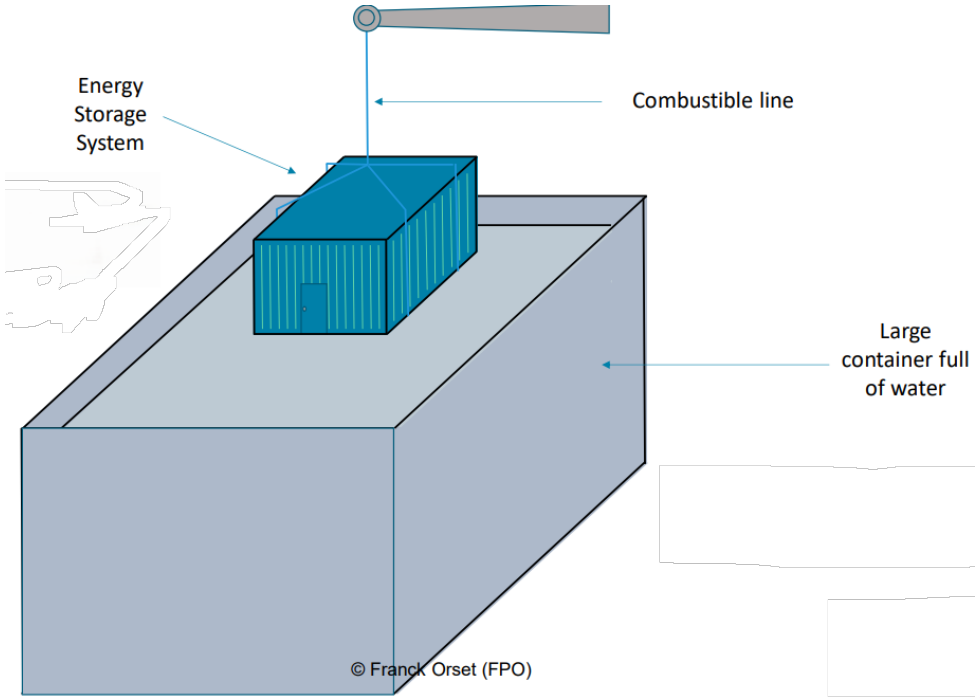
SCOR
The Art & Science of Risk

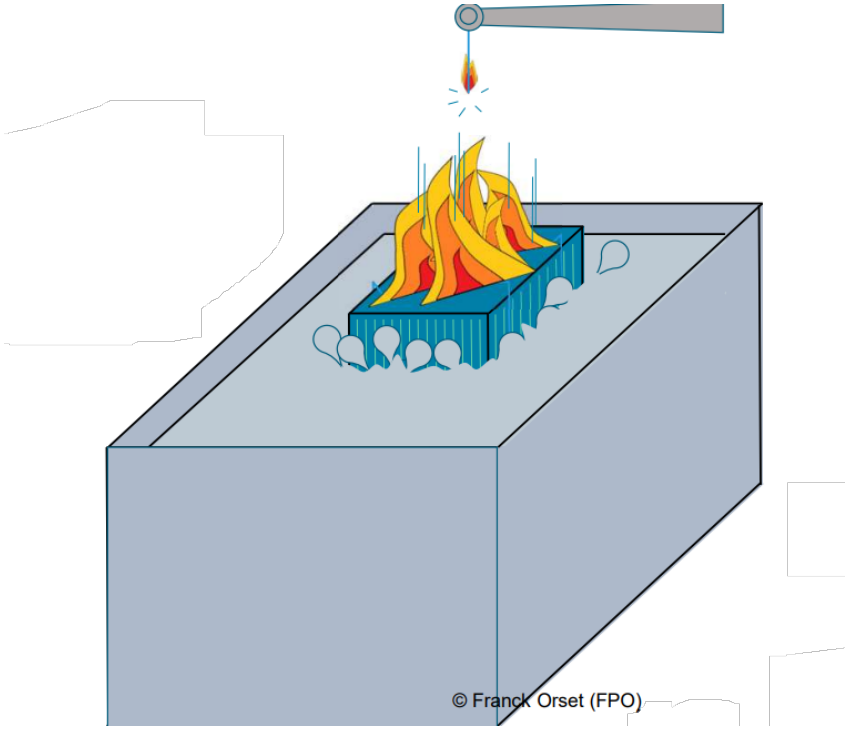
BESS
UW Info Required

- Location
- Layout / Physical Separation between / within operating blocks / containers
- Compliant with Standard & Codes NFPA 855 / UL9540 / UL9540A etc.
- Manufacturer of battery cells and modules (including type)
- Manufacturer warranty conditions
- New batteries or 2nd life batteries
- Additional Fire fighting Concept
- Contractor Experience

SCOR
The Art & Science of Risk

What shall we do if there is a fire?





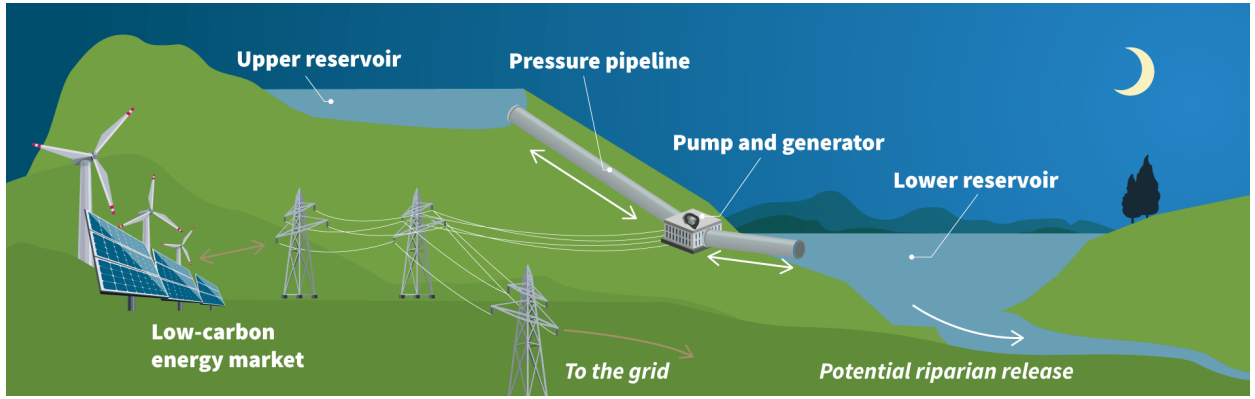
Source: Frank Orset (FPO)

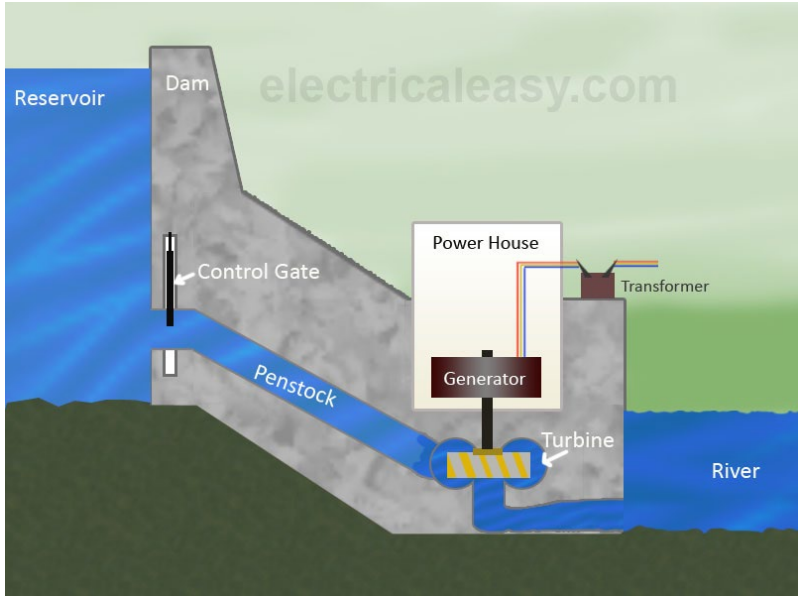
SCOR
The Art & Science of Risk

4. Pumped Storage Plant

Pumped Storage Plant
What is the difference between PSP and HPP

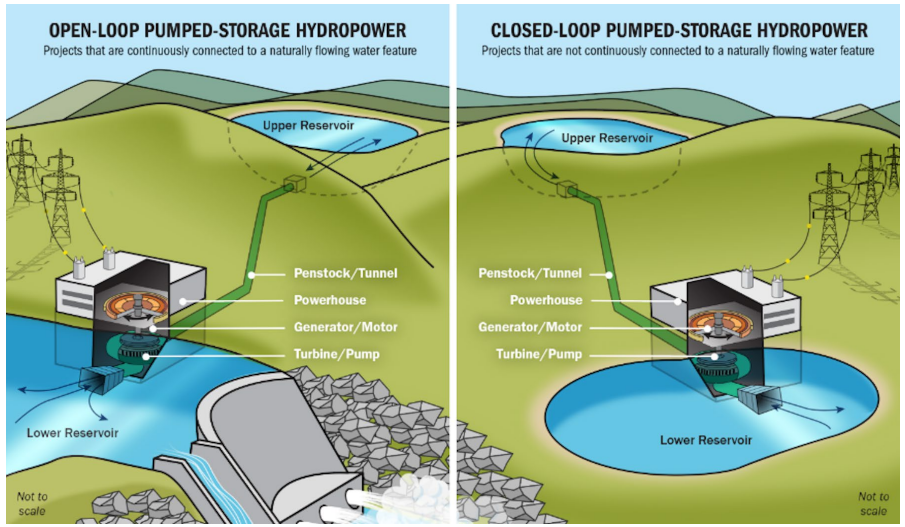
- Structure & Components
- Core Function
- Operation Mode
- Efficiency
- Site selection & construction period
- Impact to environment

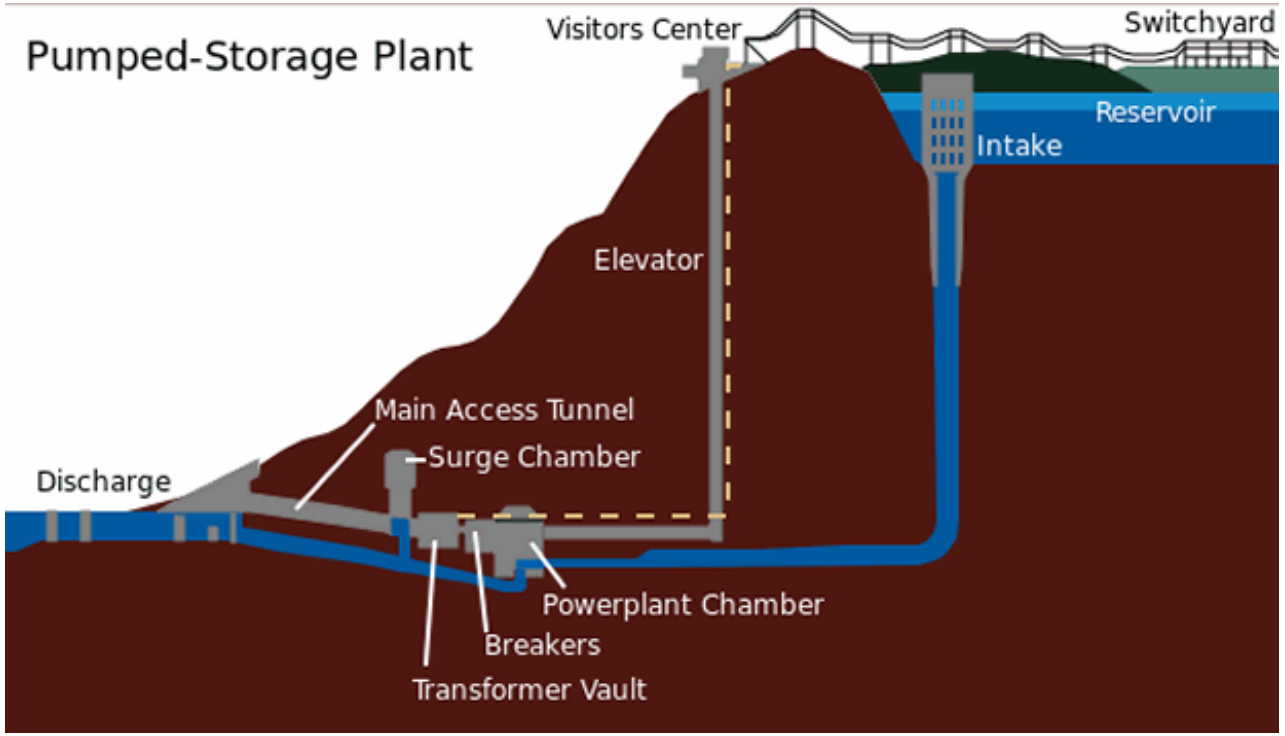




SCOR The Art & Science of Risk

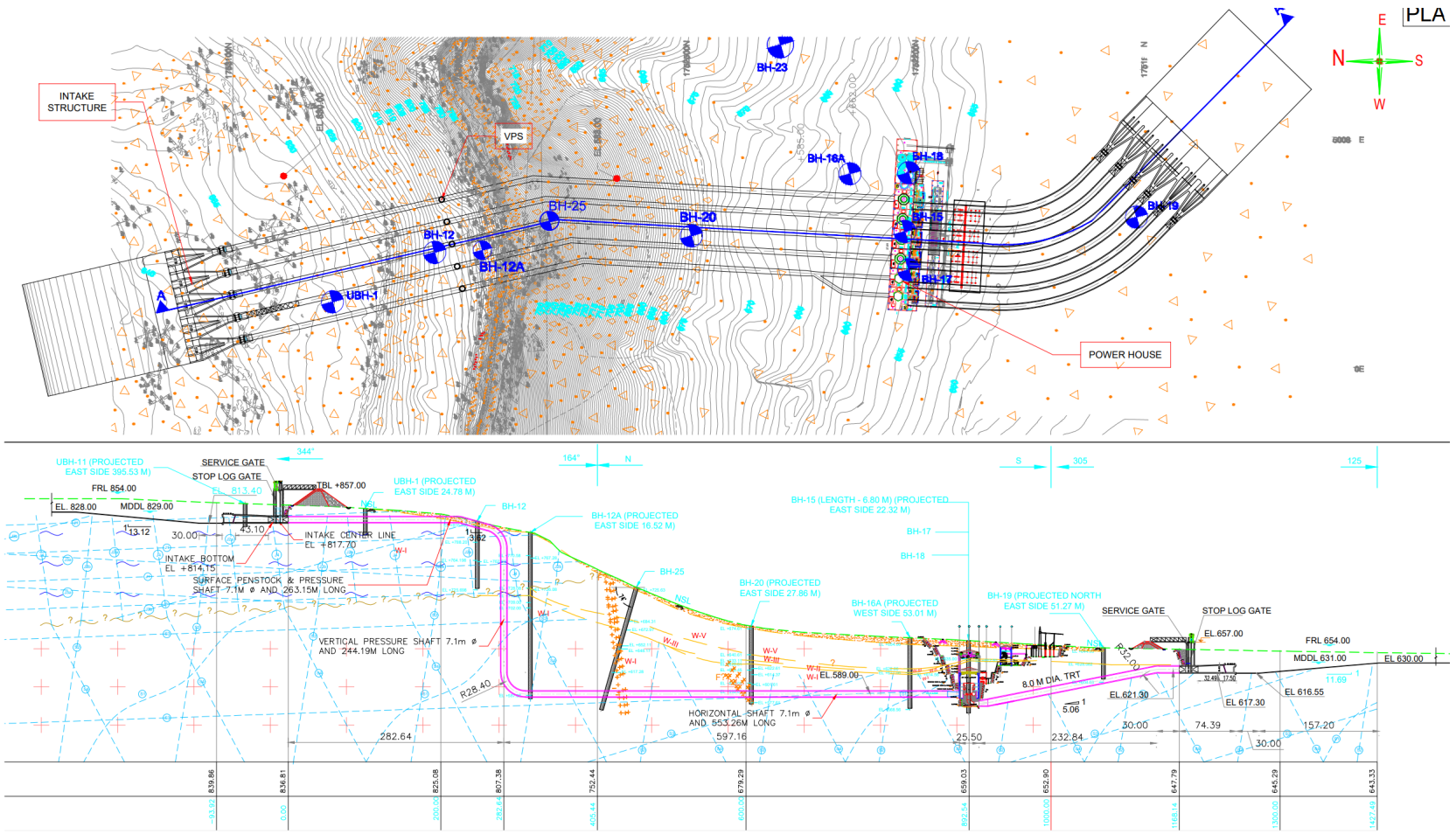
Pumped Storage Plant
Structure





SCOR
The Art & Science of Risk

Pumped Storage Plant
Geotechnical Condition

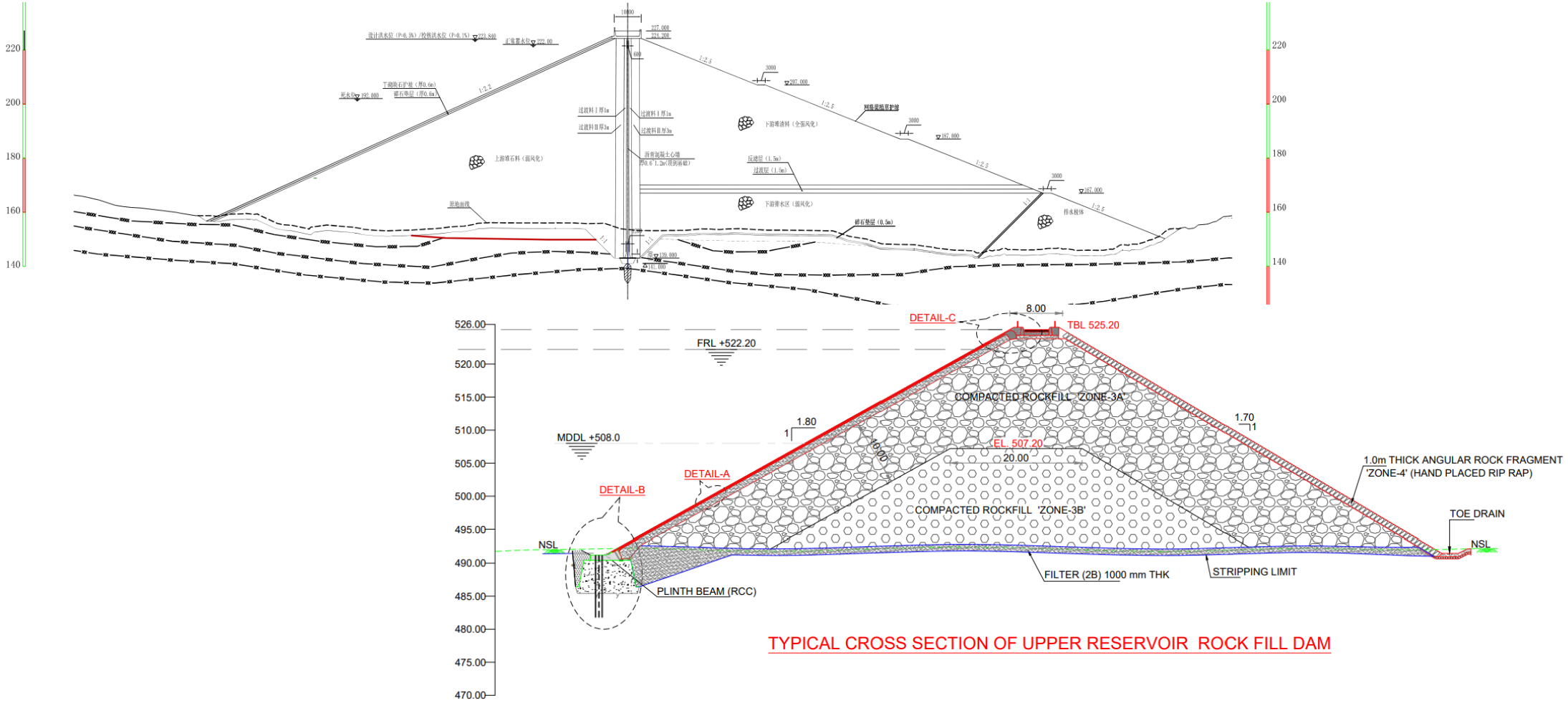


INDEX

- OVERBURDEN
- QUARTZITE
- GRANITE
- INFERRED CONTACT OF SLOPEWASH & BEDROCK
- W-I — FRESH ROCK
- W-II — SLIGHTLY WEATHERED ROCK
- W-III — MODERATELY WEATHERED ROCK
- W-V — COMPLETELY WEATHERED ROCK
- B.H. 12 — EXPLORATORY DRILL HOLE
- ? — LITHO CONTACT
- FRACTURED ZONE
- J2 — TRACES OF DISCONTINUITY
- EXPLORATORY DRILL HOLE

SCOR The Art & Science of Risk

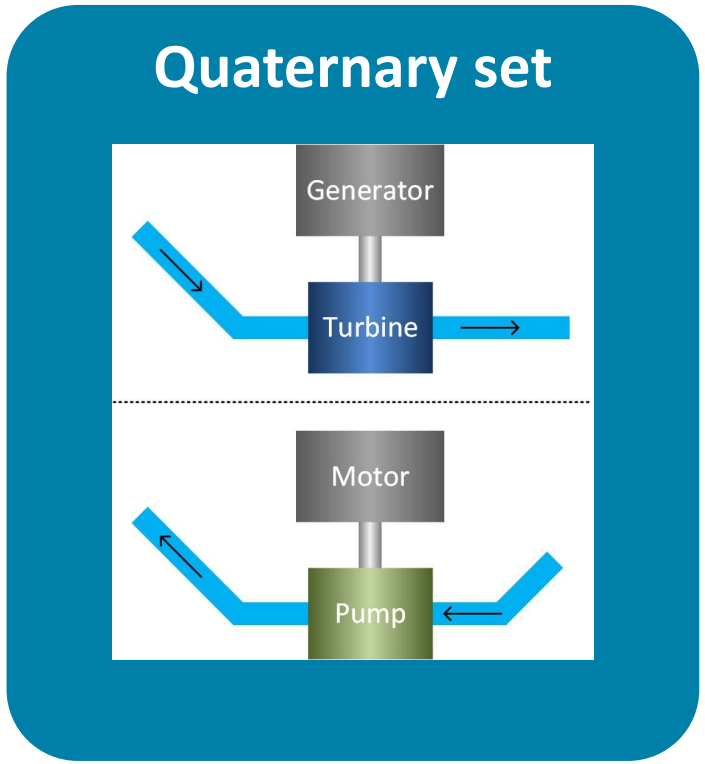
Pumped Storage Plant
Dam

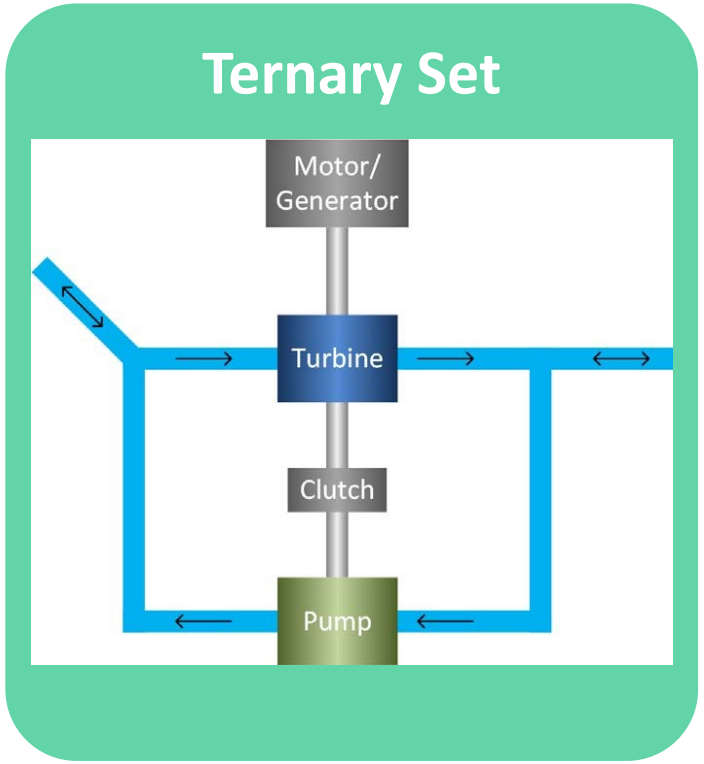


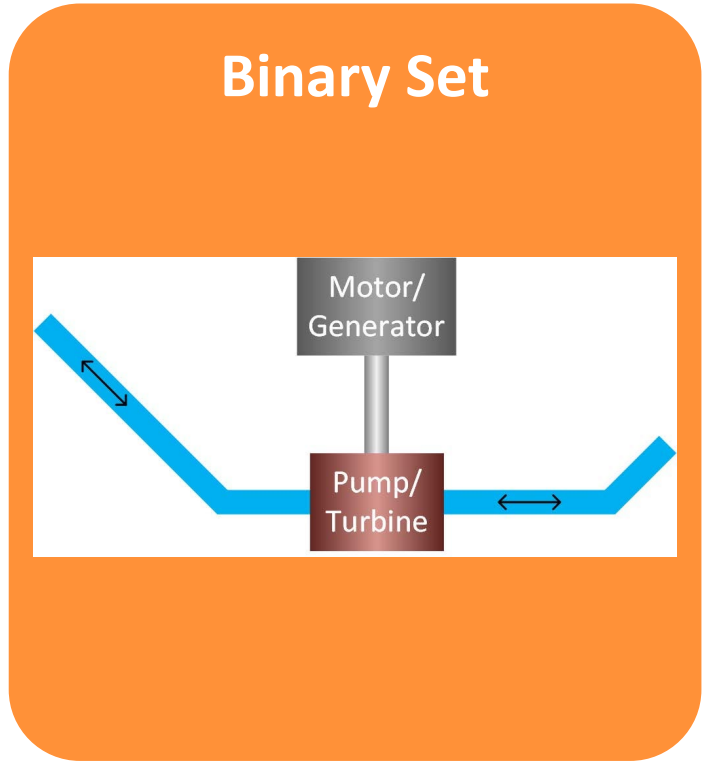
TYPICAL CROSS SECTION OF UPPER RESERVOIR ROCK FILL DAM

SCOR The Art & Science of Risk

Pumped Storage Plant
Power House Configuration





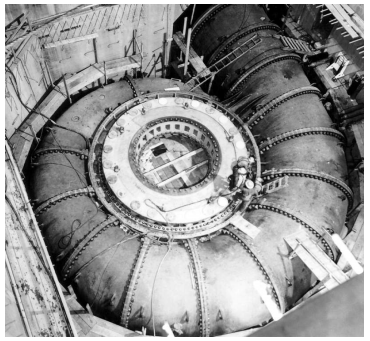


SCOR
The Art & Science of Risk

Pumped Storage Plant
Turbines

Francis Turbines

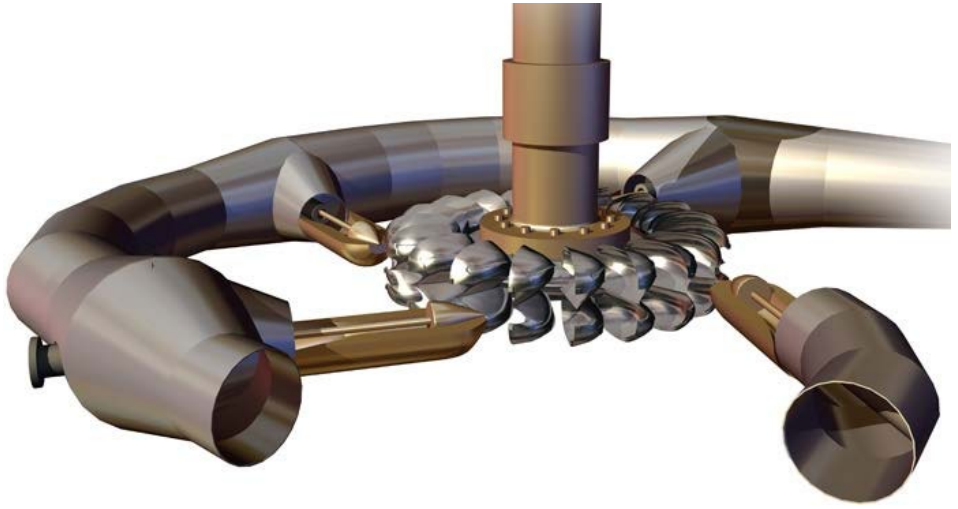
- Volute casing (scroll casing)
- Guide vanes and stay vanes
- Turbine runner
- Draft tube





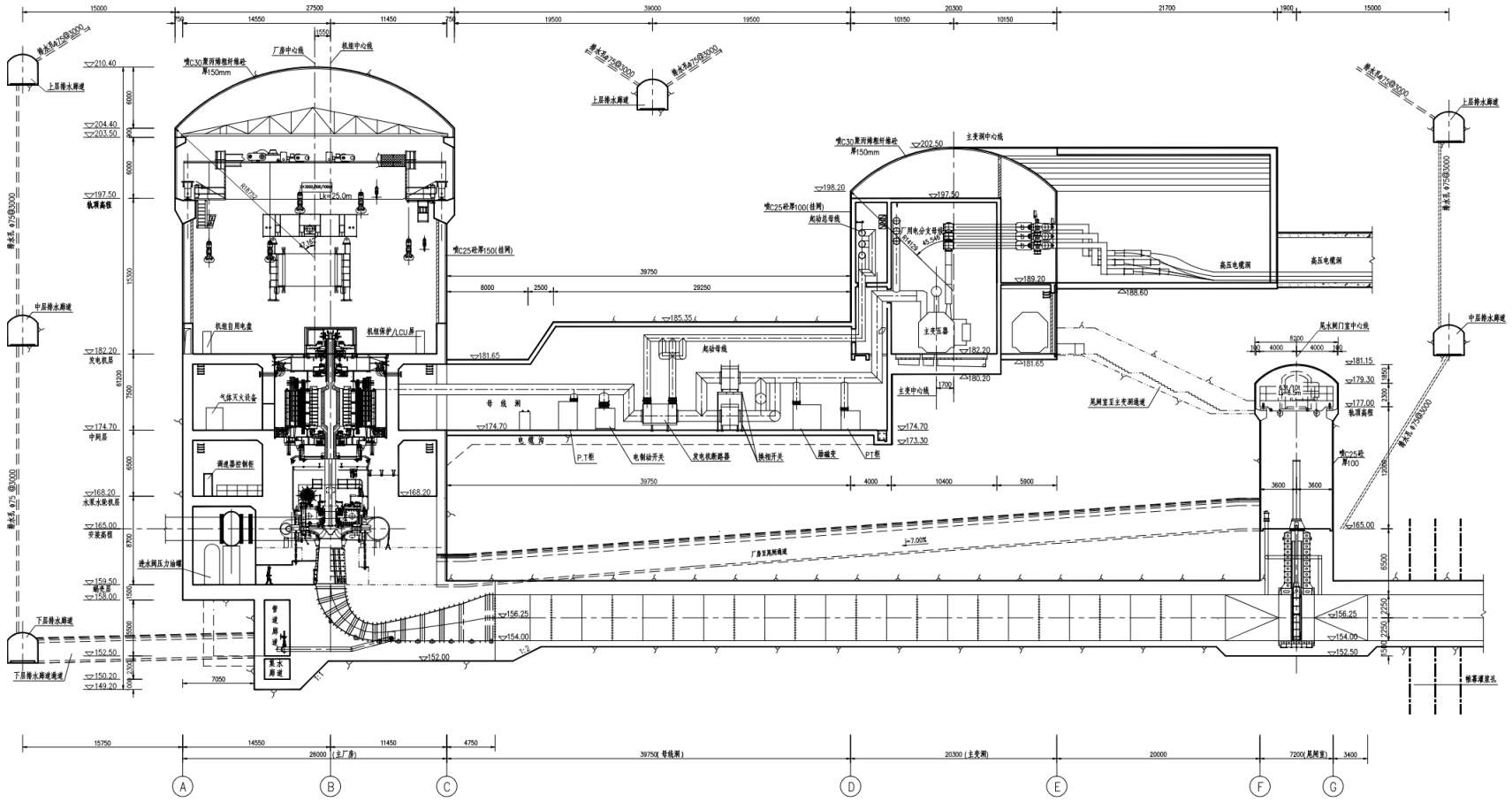
Pelton Turbines

- Impulse turbine



SCOR
The Art & Science of Risk

Pumped Storage Plant
Powerhouse



SCOR
The Art & Science of Risk

Pumped Storage Plant
UW Info Required

- Drawings
- Bar chart
- Bill of Quantities
- Geotechnical / Hydrological Report
- Construction Methodology
- Technical specification for main equipment (including reference)
- Contractor Experience

SCOR
The Art & Science of Risk

Pumped Storage Plant
Risk Exposure

- NH exposure – Earthquake / Windstorm / Flood
- Geotechnical condition – Landslide / Leakage
- Mechanical Failure – Turbine / Generator Failure
- Civil Structure – Dam / Penstock
- Site access road – Attritional
- Designer / Contractor experience – Manmade Errors

SCOR
The Art & Science of Risk

Pumped Storage Plant
PML Scenarios

- Natural Hazard
- Fire / Explosion
- Mechanical Failure

SCOR
The Art & Science of Risk

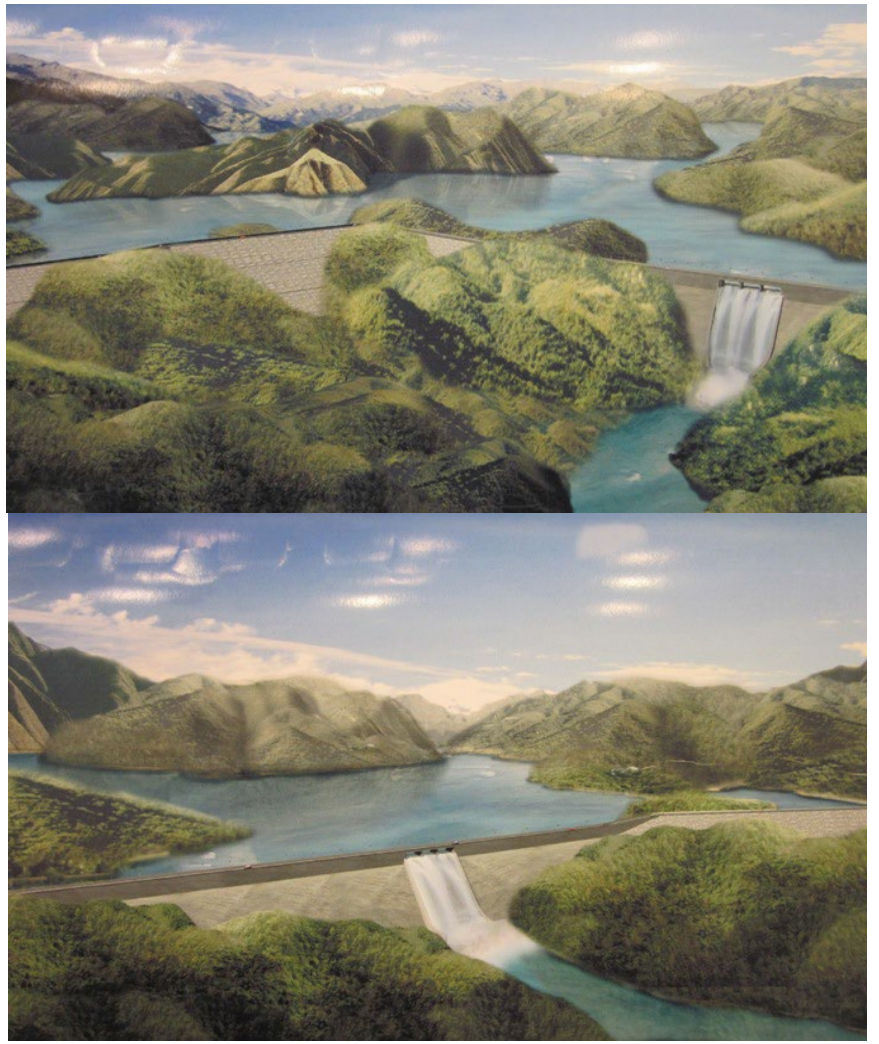
Pumped Storage Plant
Loss Experience

2006 Huizhou Pumped Storage Plant, China

Main hoisting wire rope snapped, rotor fell from ~10m, rotor body and lower thrust bearing damaged and partial deformation of nearby steel structures

Cause: Insufficient breaking strength wire rope is selected, miss in hoisting plan, management failure.

Loss: EUR 3M - 5M



Hydropower Journal (2007 Suppl.) – *Pumped Storage Accident Case Studies*.

SCOR The Art & Science of Risk

Pumped Storage Plant
Loss Experience

2016 Fengning Pumped Storage, China

Landslide, Partial collapse of the upper reservoir excavation slope

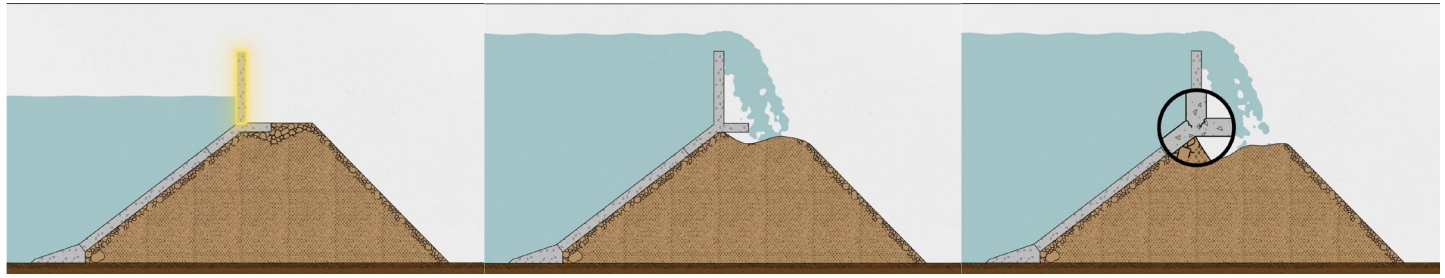
Cause: Continuous heavy rainfall, Complex Geological Conditions, Inadequate Design and Construction Adjustments

Loss: EUR Few Millions



State Grid of China switches on world's largest pumped-hydro station – pv magazine International

Pumped Storage Plant
Loss Experience



2005 Taum Sauk pumped storage plant, US

Upper reservoir's rockfill embankment breached

Cause: Water continued to be pumped into the upper reservoir after it had reached capacity, led to overtopping and the failure reservoir wall.

Loss:



The Wild Story of the Taum Sauk Dam Failure — Practical Engineering

5. Floating Solar

Floating Solar
Why do we use Floating Solar

Advantages

- Ideal for high density population
- Higher Energy Yield
- Water Benefit

Disadvantages

- High initial investment
- Complex Installation and operation/maintenance
- Impact to environment

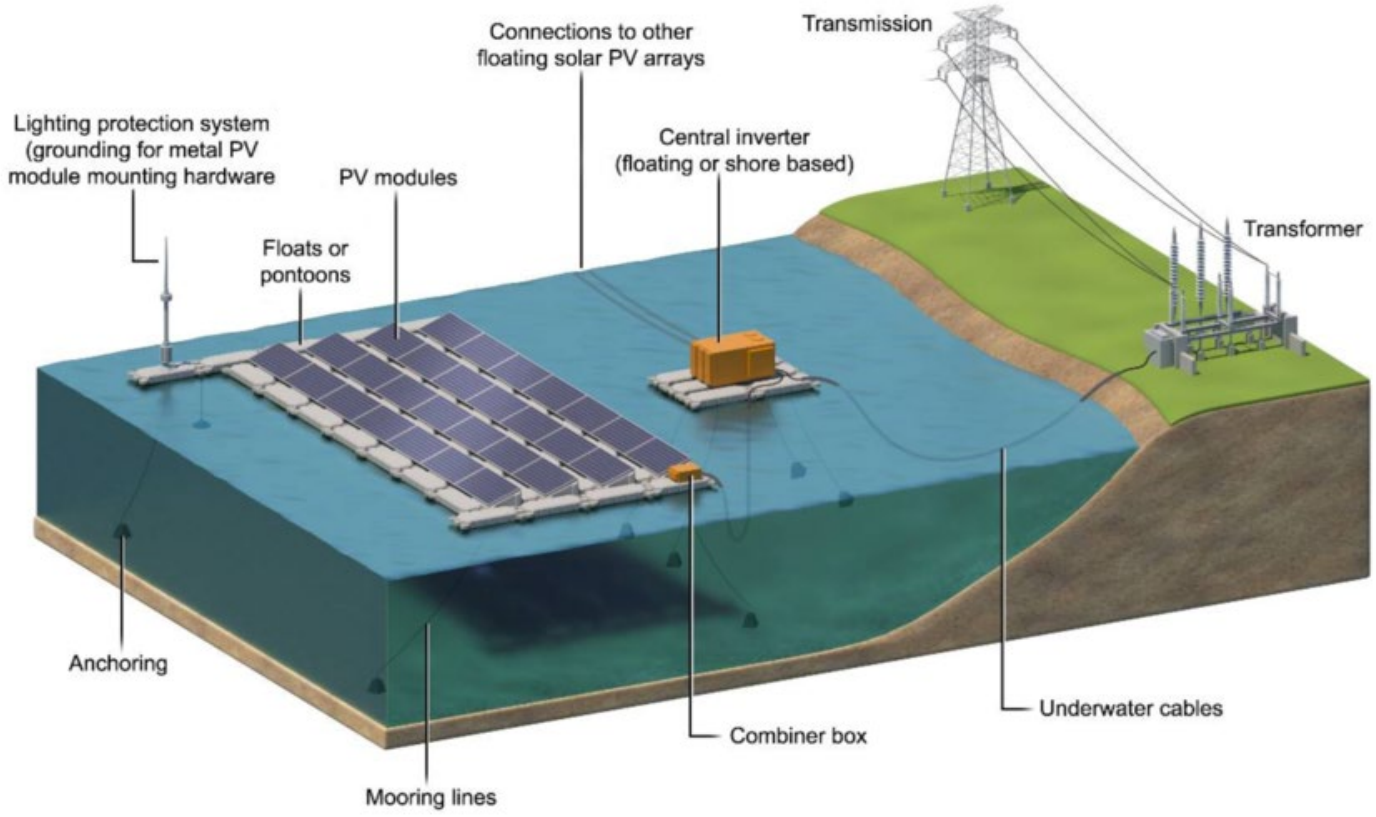
SCOR
The Art & Science of Risk

Floating Solar PV
UW Info Required

- Location
- Solar Panel Model and Manufacturers
- Type of Floating Structure, Anchoring and Mooring System
- Cable management
- Inverter / Transformer Placement
- Construction Methodology and Barchart
- Contractor Experience
- Biofouling and Corrosion

SCOR
The Art & Science of Risk

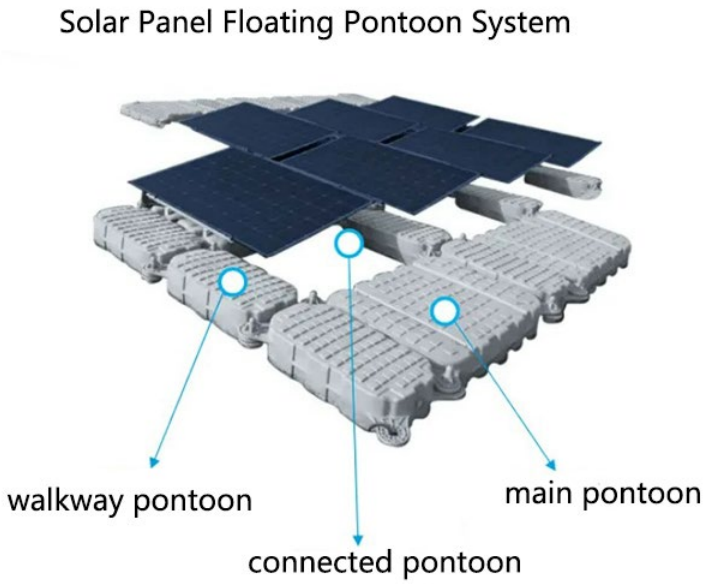
Floating Solar
Components

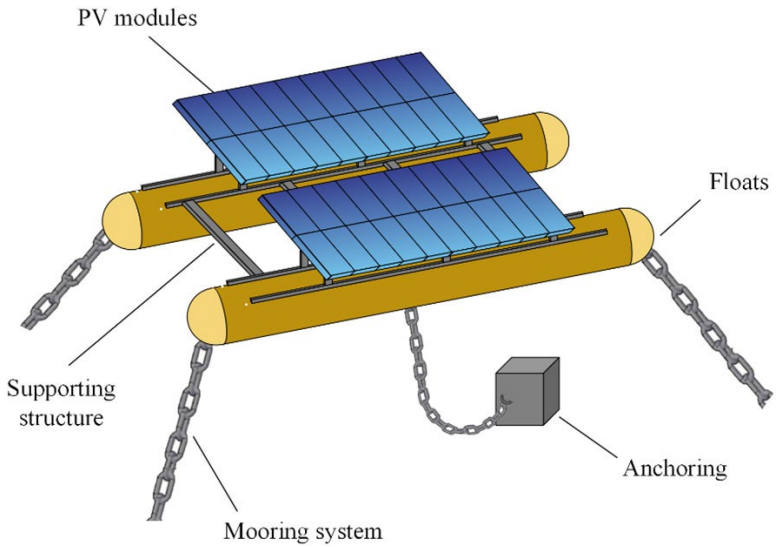


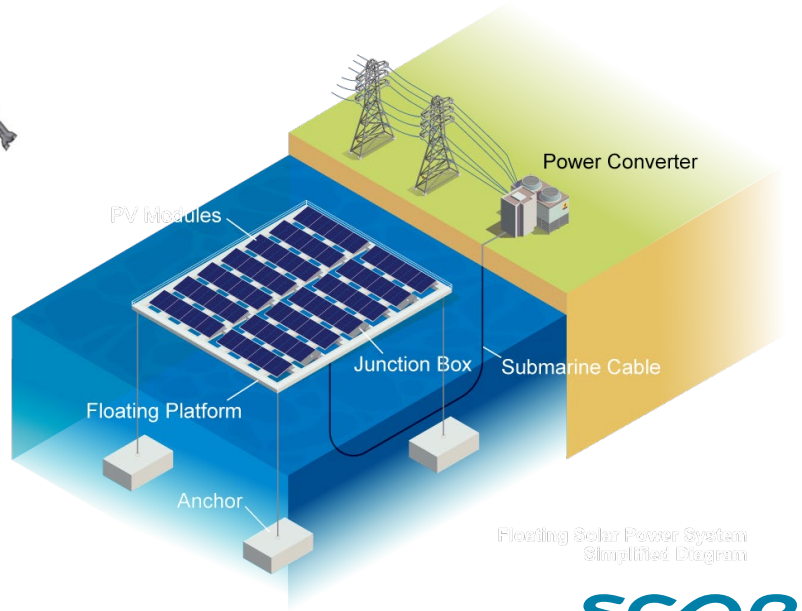
- Floating Structure
- Module mounting structures
- Mooring system
- PV modules
- Inverters
- Balance of system (BOS)

SCOR
The Art & Science of Risk

Floating Solar
Floating Structure



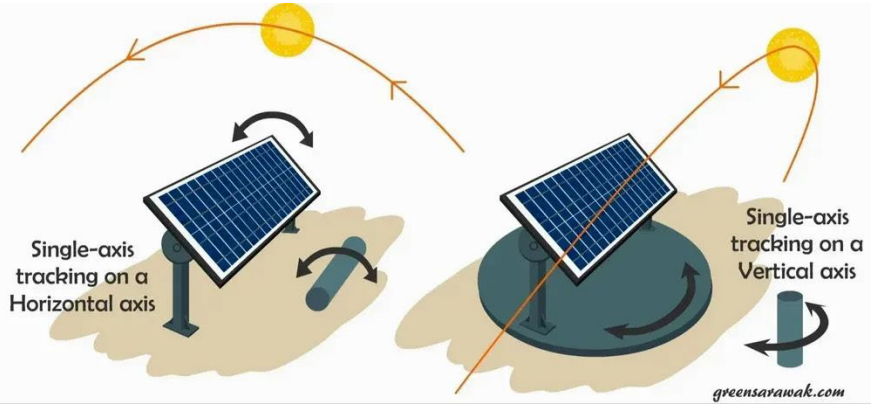




SCOR
The Art & Science of Risk

Floating Solar
Module mounting Structure





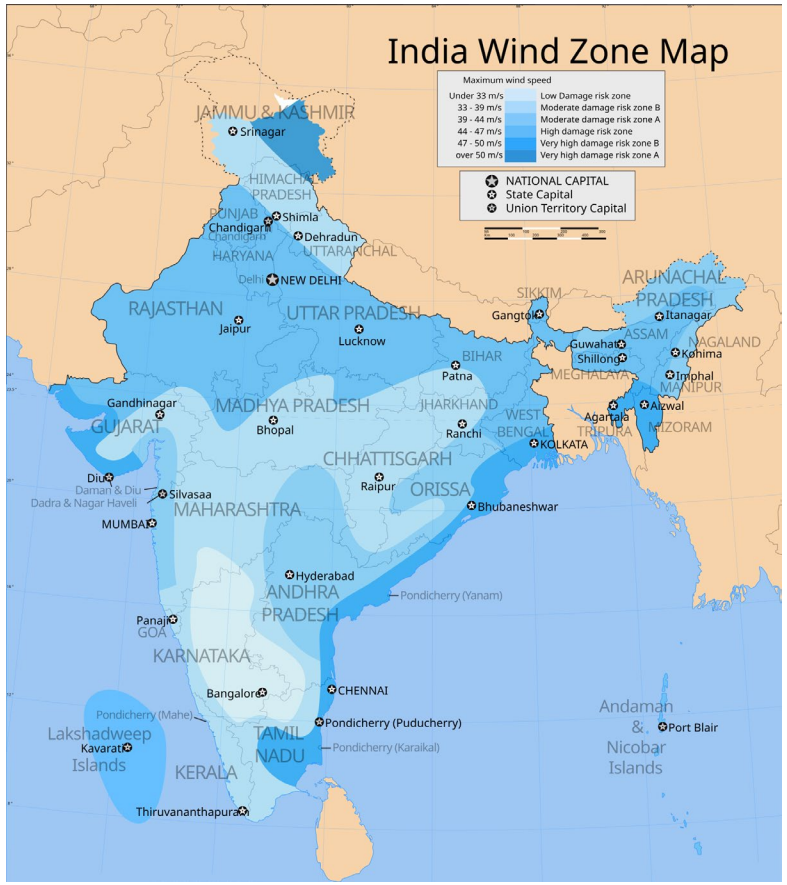
SCOR
The Art & Science of Risk

Floating Solar
Mooring Structure

Anchoring Type	Holding Capacity	Cost	Installation Complexity	Best For
Gravity	Low-Medium	Low	Easy	Small ponds, stable water
Pile	High	High	Hard	Rocky bottoms, high wind
Drag Embedment	Medium-High	Medium	Moderate	Sandy/muddy beds
Screw / Helical	Medium-High	Medium	Moderate	Clay/silt, moderate depth
Mooring Lines + Elastic	Medium	Medium	Moderate	Fluctuating water levels
Shore-Based	Low	Low	Easy	Near-shore, small scale
Tension Leg Platform	Very High	Very High	Complex	Deep water, offshore

Floating Solar
Risk Exposure

- Natural Hazard
- Floating / Mooring System Failures
- Electrical Failure
- Human Error
- Operation and Maintenance
- Biofouling



SCOR
The Art & Science of Risk

Floating Solar
Loss Experience



2019 Kyocera Yamakura Dam array, Japan

Typhoon No. 15 sweep through Japan's largest floating PV installation in Chiba prefecture. TCL Solar's 13.7 MW

The weekend read: Don't throw caution to the wind – pv magazine International

Floating Solar
Loss Experience

2022 - O'Mega 1 power plant, France

violent winds blowing up to 80km/h in gusts causing the cables connecting the modules to the junction boxes became bare, leading to a short circuit on one of the three-panel floaters of the power plant. The affected inverters were shut-off but three floats ignited.



Akuo speaks out on recent fire accident at its 17MW floating PV plant in France – pv magazine International

Floating Solar
Loss Experience



2024 - Omkareshwar Dam Floating Solar Plant, India

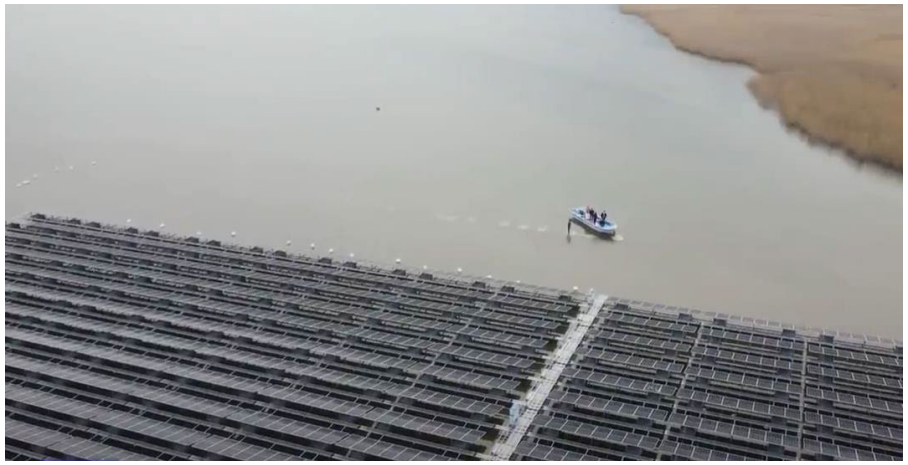
Suffered severe damage during a storm with winds reaching 50 km/h.

2024 - Bhakra Nangal Floating Solar Plant, India

A large number of solar panels were washed away, leading to significant losses.

Two Largest Floating Solar Plants in India Suffered Severe Damages | IndianWeb2.com

Losses
Or not?









SCOR
The Art & Science of Risk

Floating Solar
Risk Mitigation

- Design standard and Code
  - ✓ IEC 62738 – Guidelines for floating PV design.
  - ✓ DNV-RP-0584 – Certification for floating solar structures.
- Operation and Maintenance Monitoring
- Emergency Response Plan

SCOR
The Art & Science of Risk



Thank You

Elsie WANG / Pui Fong HAN
Engineering Team
May 2025

Mumbai, India

SCOR
The Art & Science of Risk