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Hydrogen from hydro-power
High potential for Pakistan

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World Hydrogen Leaders – Asia Focus

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Introduction to Stephen B. Harrison and sbh4 consulting

Stephen B. Harrison is the founder and managing director at sbh4 GmbH in Germany. His work focuses on decarbonisation and greenhouse gas emissions control. Hydrogen and CCUS are fundamental pillars of his consulting practice. He is also the international hydrogen expert and team leader for two ADB projects related to renewable hydrogen deployment in Pakistan and Palau in Asia.

With a background in industrial and specialty gases, including 27 years at BOC Gases, The BOC Group and Linde Gas, Stephen has intimate knowledge of hydrogen and carbon dioxide from commercial, technical, operational and safety perspectives. For 14 years, he was a global business leader in these FTSE100 and DAX30 companies.

Stephen has extensive buy-side and sell-side M&A due diligence and investment advisory experience in the energy and clean-tech sectors. Private Equity firms and investment fund managers and green-tech startups are regular clients.

As a member of the H2 View and **gas**world editorial advisory boards, Stephen advises the direction for these international publications. Working with Environmental Technology Publications, he is a member of the scientific committees for AQE 2021 and CEM 2023 - leading international conferences for Air Quality and Continuous Emissions Monitoring.

Green hydrogen production from renewable power and water on an electrolyser

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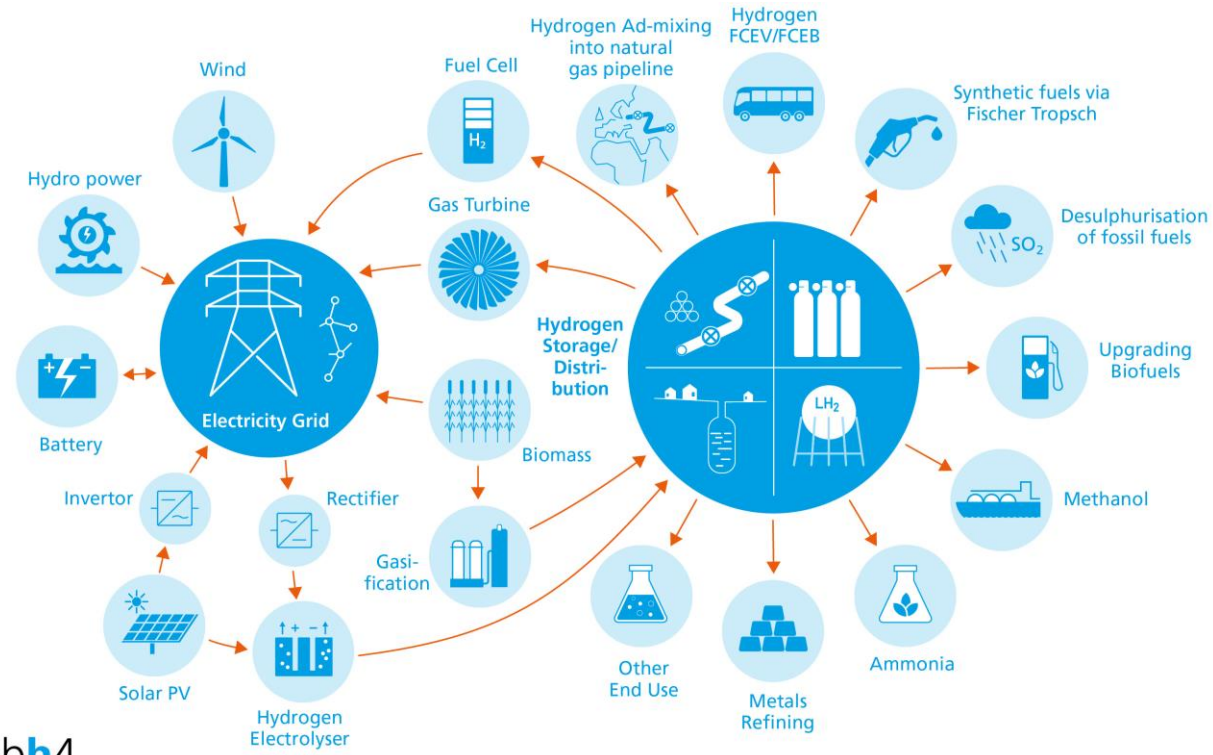

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Pakistan has good potential for renewable geothermal power and energy

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Pakistan has good potential for renewable wind power

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Wind farm in Pakistan

Pakistan has almost unlimited potential for renewable solar power

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Solar panels in a mountainous region of Pakistan

Pakistan has unrivalled potential for renewable hydro-electric power

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Why hydrogen from hydro in Pakistan?

- Hydrogen production is possible from abundantly available and potential future renewable hydro power resources in Pakistan
- Hydrogen has excellent long term energy storage ability for time-shifting for annual power supply security
- Pakistan has the potential for underground hydrogen storage in salt caverns as storage for seasonal hydro power generation capacity
- Green hydrogen from renewable power and electrolysis can support national and international climate change targets
- Hydrogen is a clean source of energy at the point of use
- Hydrogen has similar handling and safety characteristics to natural gas and existing gas infrastructure can be modified and leveraged

Hydro power from existing and proposed mega-dams can be applied to large alkaline base-load electrolysers

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The Tarbela dam in Pakistan

Like wind and solar, hydro is also “variable renewable energy” – in slow motion!

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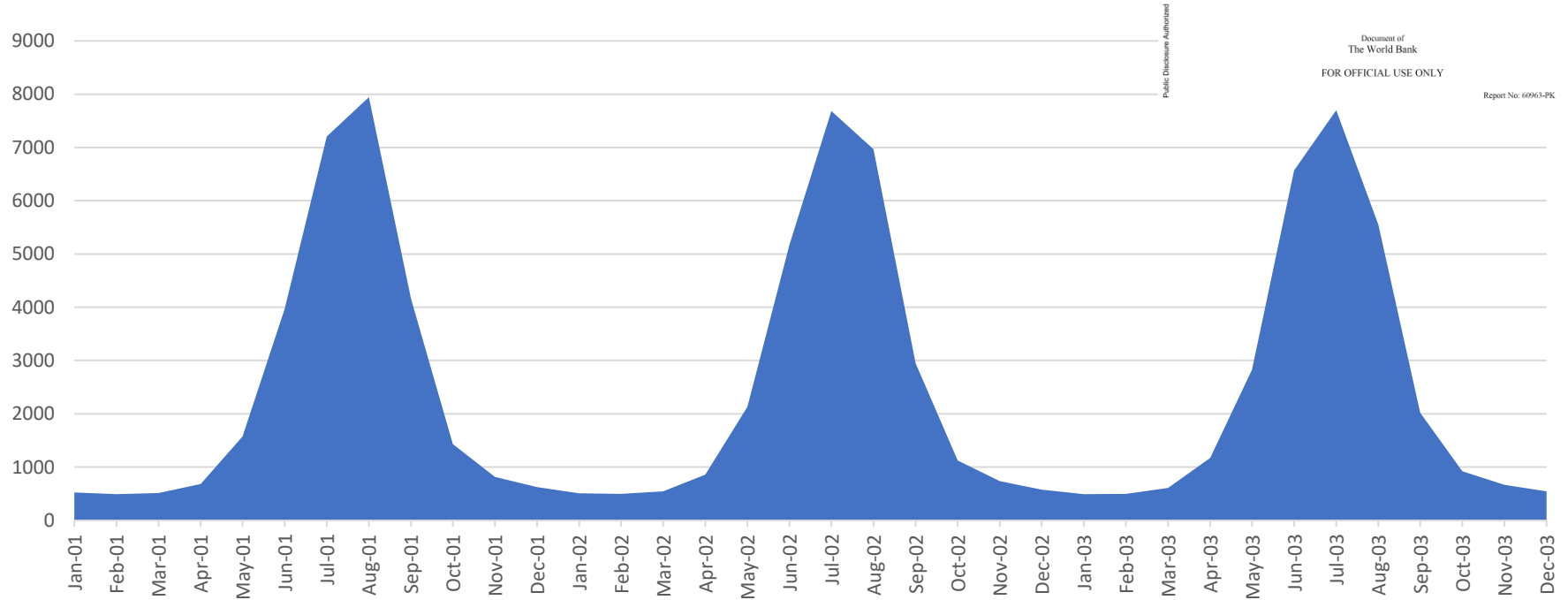

Time cycles for solar and wind are day / night or week to week. Hydro power has seasonal cyclicality.

Giga-scale underground hydrogen storage can bridge seasonal imbalances in power supply and demand

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The large Tarbela hydro dam in Pakistan produces very little power in late winter / early spring before the rainy season begins

Cost-effective large-scale, long-term hydrogen storage can be achieved in salt caverns

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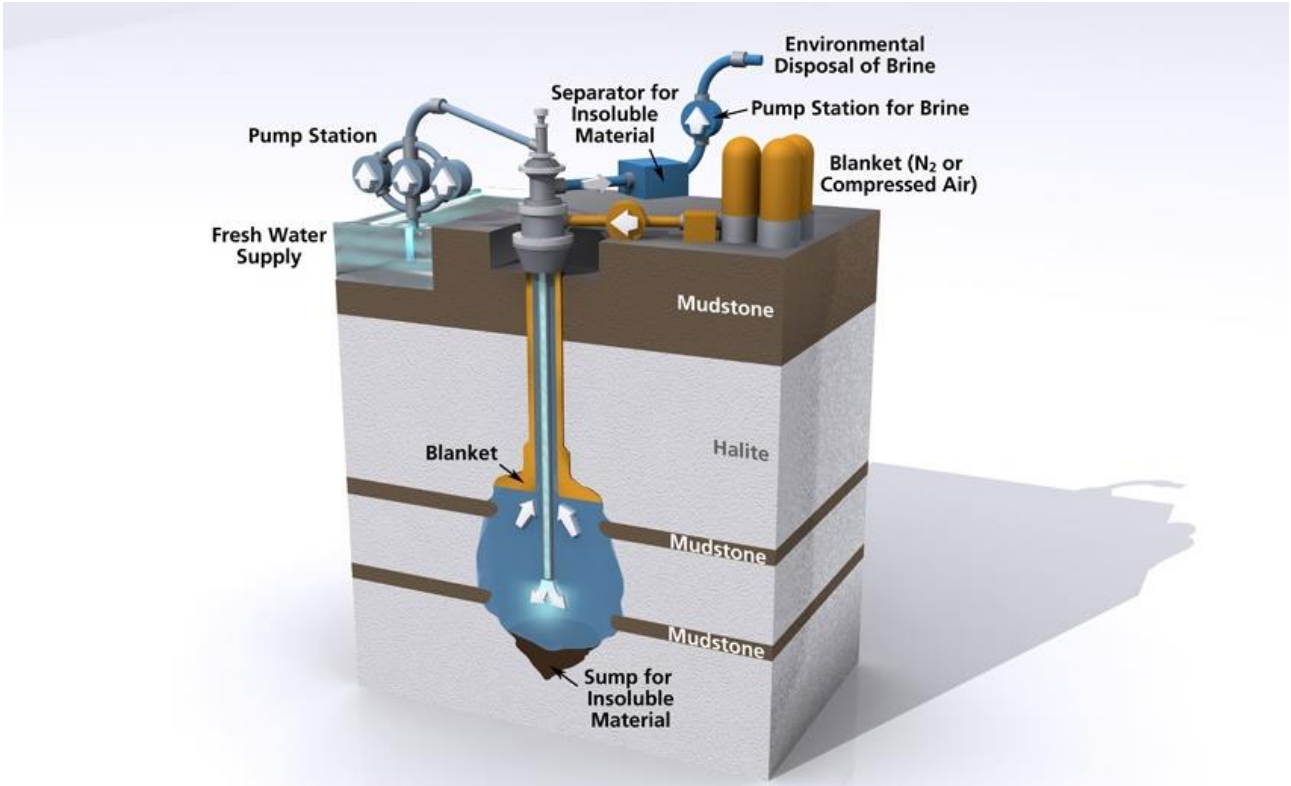

Multiple underground gas storage caverns can be created to achieve the required storage volume

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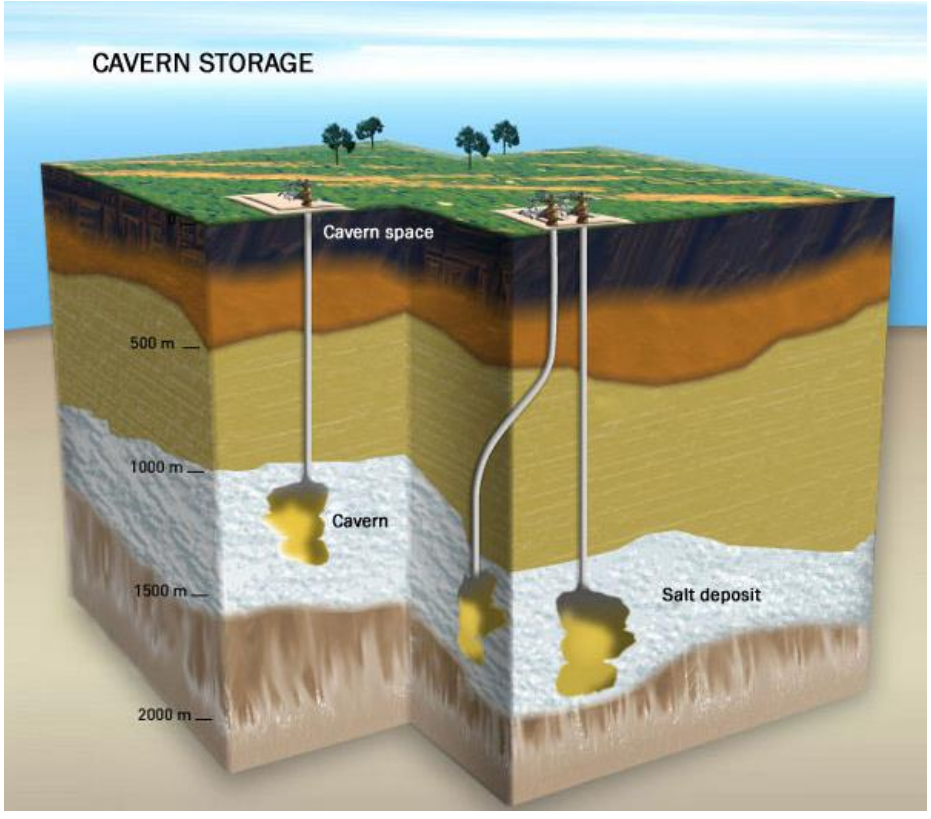

The potential for low-cost underground hydrogen storage in salt-caverns depends on geological formations

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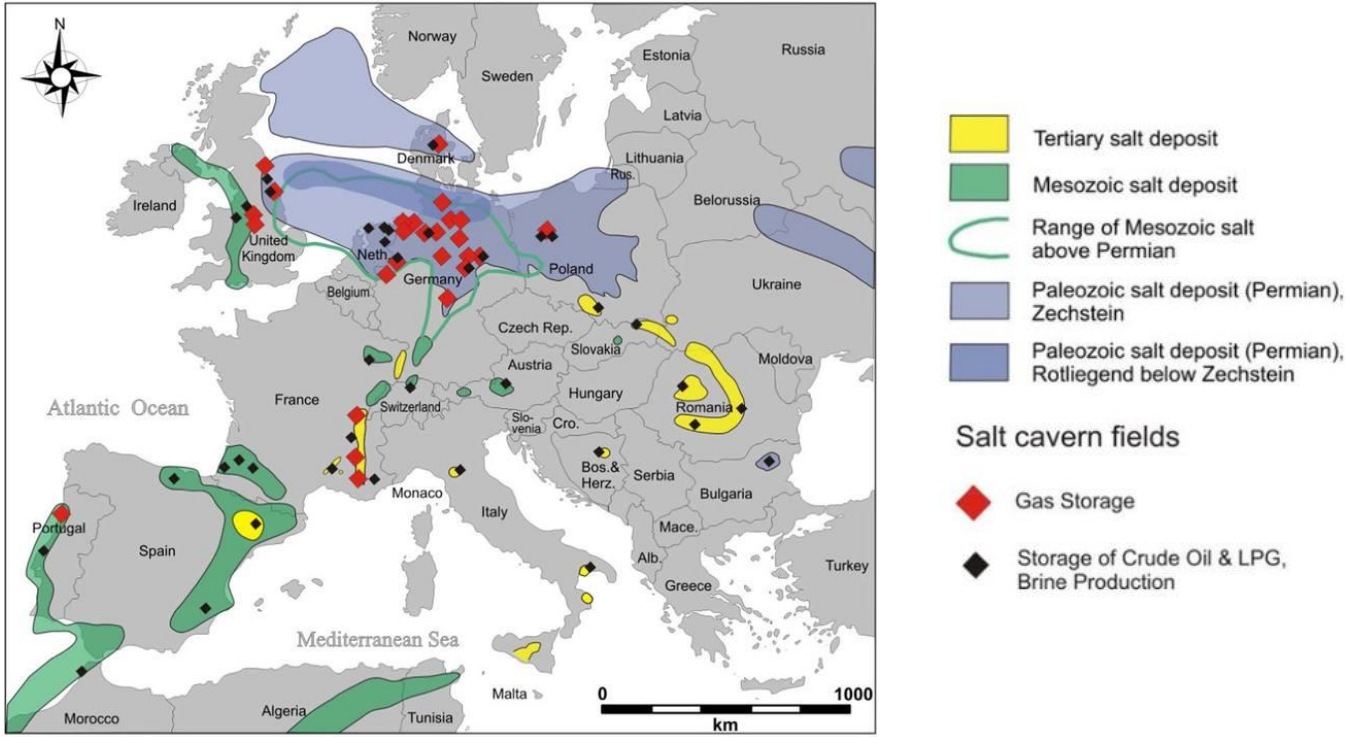

Underground salt caverns for seasonal hydrogen storage and time shifting – best potential zone

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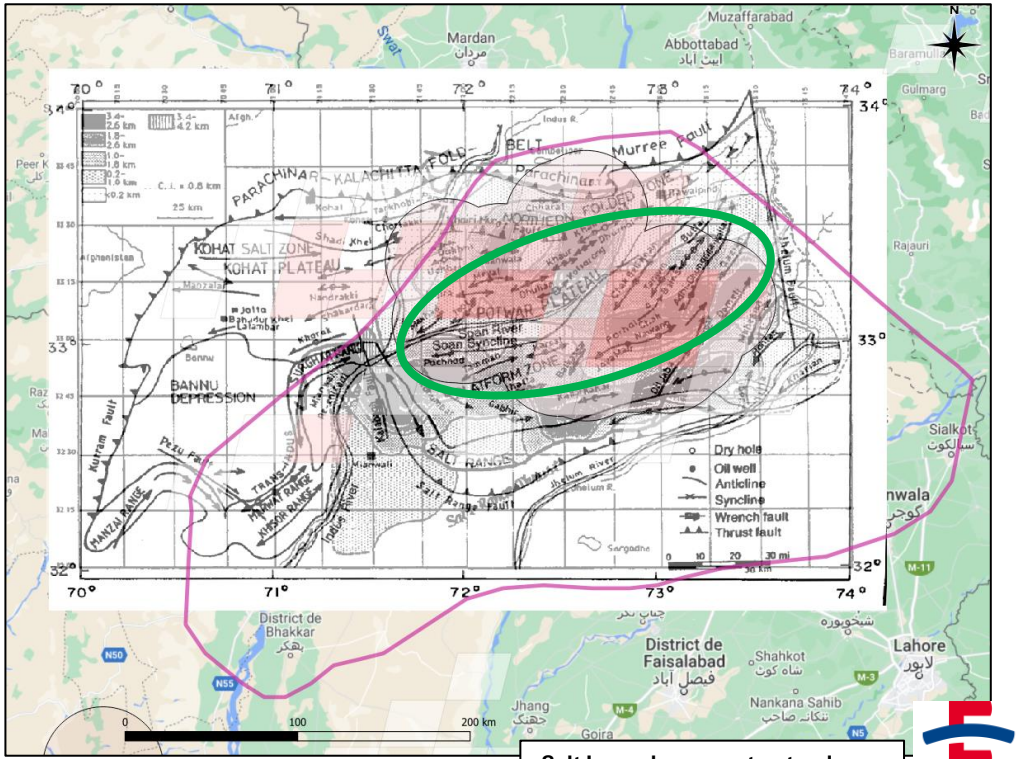
Good potential in the Potwar Plateau

- Salt is thick (up to >3km)
- Salt is clean - 95% to 99%
- Potash might be present
- Folding and thrust in the central part: anticlines are cored with salt formation
- Existing deep petroleum data: wells / seismic

Risks to be further evaluated

- Salt depth may be very deep, >2000m
- High tectonical structuration (dome,
- decollement, thrusting)
- Borders of the area where the salt is less deep are located on regional thrust belts, salt might be reduced to thrust slice



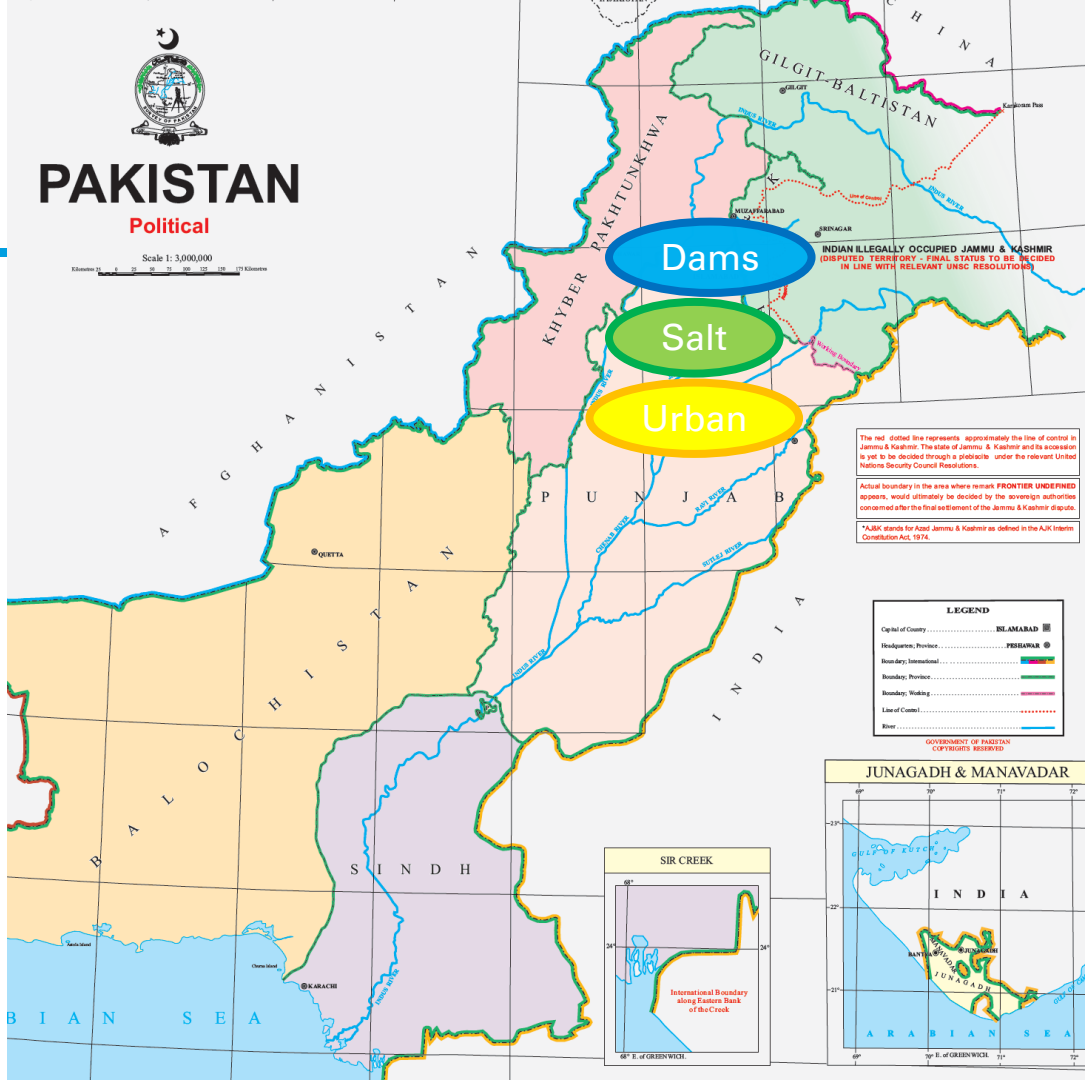
Salt Isopach map + structural map + well density

Information on this slide kindly provided by Louis Londe, Geostock

GEOSTOCK ENTREPOSE GEOSTOCK GREEN STORAGE

Sometimes luck, or Allah, is with you…

- The mega-dams and the salt plateau are close to each other in the north of Pakistan
- Hydrogen or power transmission costs from the dams to the salt caverns are limited
- The salt caverns are close to the new gas grid section that unites the northern and southern transmission networks
- The salt caverns are also close to one of the most densely populated regions where hydrogen for cooking, heating and power generation is required



Micro-hydro power from small new run-of-the-river schemes can be used on small PEM electrolysers

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Mountain river in northern Pakistan. Water may freeze in winter meaning zero hydro power.
Seasonal energy storage in these locations will need smaller scale, localised solutions. Hydrogen might not be the right answer.

Hydrogen is not ‘magic’…

- Green hydrogen is derived from biomass or renewable power or fossil fuels – there are inherent conversion costs and energy losses
- Direct use of renewable power can be more cost effective – but large-scale, long-term electricity storage is difficult and expensive, hydrogen can help with energy storage
- Only low-carbon hydrogen will reduce climate change – grey and black hydrogen are dominant in the world today and this must change
- Hydrogen alone is not the answer – it deserves to be part of an appropriate and sustainable mix of solutions

An affordable, decarbonised future will require a mix of appropriate technologies

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And the transition will be worth the investment and effort, to guarantee a sustainable future for the children of Pakistan

And the best route through the energy transition is largely dependant on local conditions

- Hydro power to hydrogen in Australia?
  - No thanks, we'll use solar.
- Solar power to hydrogen in Scotland?
  - Not really, we'll use wind.
- Salt caverns for underground hydrogen storage in South Africa?
  - Nice idea… but we'll keep digging for gold!

Yes, each of those national and regional hydrogen strategies is required!

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