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Stage Resume of Underground Gas Storage Development in China, Perspectives and New Challenges

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- Market situation and Need of UGS
- Main technical challenges for a rapid UGS portfolio growth
- The economical challenges: Regulation and Pricing
- Conclusion

Executive summary

- The development of underground gas storage (UGS) in China is still at preliminary stage; however, fast growing natural gas consumption will request significant modulation capacity. To better develop UGS, it is important to surpass the related market, technical and economical challenges.
- This paper aims to present the current situation and study the solutions. The methods should take into account both Chinese particular situations and the international experiences, which indicates a pragmatic and step-by-step approach.

Executive summary

- Currently, UGS development (working capacity of 4.7 bcm, 3% of consumption) in China is not sufficient to meet gas modulation demand (20% as reference ratio worldwide); this ratio will remain low in short term (12 bcm of UGS vs. 24 bcm of modulation need in 2020).
- Petrochina is the main player of UGS development, and is involved in all kinds of conventional technologies: depleted, aquifer and salt caverns.
- The majority of UGS are issue of depleted fields which are not always close to consumption regions that need modulation tools for both seasonal and emergency peak shaving.

Executive summary

- China continues to invest in natural gas pipeline to link production areas with domestic gas markets and in UGS for more flexibility.
- Development of salt caverns & the conversion of depleted oil/gas fields request 5 to 10 years but China has to face with “incompressible” time constraint to build its ambitious UGS portfolio.
- Despite exhaustive site screening studies including alternative UGS solutions, the identified sites lead to technical challenges and make UGS development more complex than expected, especially in the areas of high gas demand.
- UGS and E&P share some technical similarities but fundamentally they are strongly different and Chinese UGS developers have to palliate the lack of experience and the absence of learning curves due to the lack of UGS historical data.
- Cooperation with International UGS experienced companies is one of the key success factor allowing better efficiency and saving of time.

Executive summary

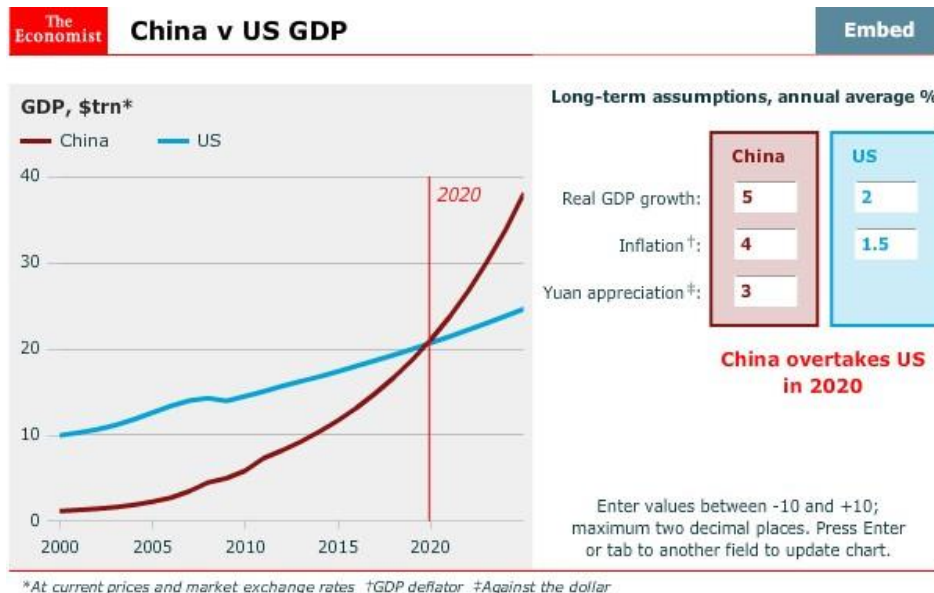
- It could be important to introduce private and international capital to participate to develop UGS, so as to accelerate modulation capacity development. Thus, the main challenge is to build a stable system giving confidence to the investors, by mitigate the perception of economical risks combined with the technical ones.
- Currently, Chinese government implemented some preliminary or trial policies related to natural gas and/or UGS reform. According to international experiences, for further evolution, it could be envisaged to de-regulated upstream and downstream and only control midstream with regulated tariff of transparency and non-discrimination in the future.

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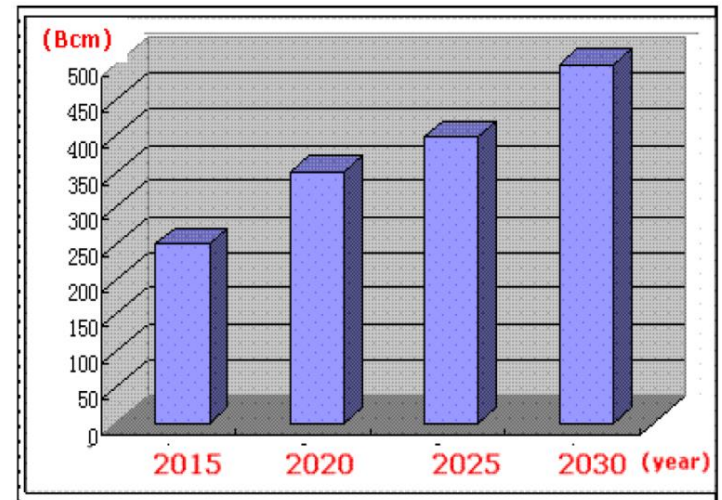
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Natural gas and UGS Market

- In order to use relatively clean resource to meet huge domestic energy demand, China is increasing fastly the consumption of natural gas in the long term: from 46 bcm in 2005 to 180 bcm in 2014; estimation of 350 bcm in 2020.



Source: [Standard & Poor's](#)

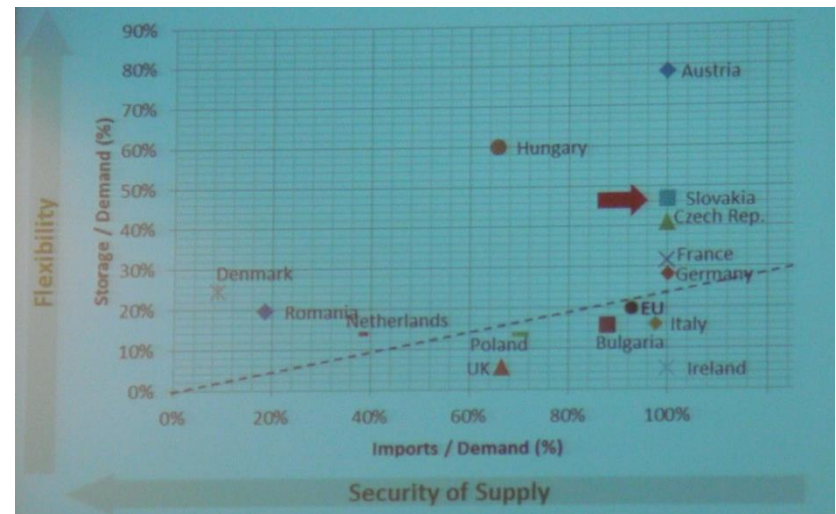
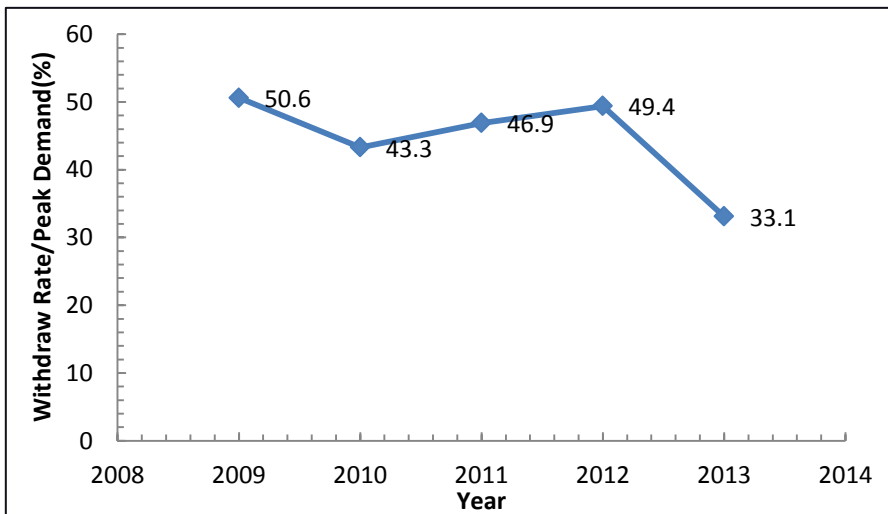


Gas consumption prediction

Source: [Chinese Academy of Social Sciences](#)

Natural gas and UGS Market

- In the mature gas markets, stable gas supply is often modulated by UGS so as to match variable demand of end-users. UGS has been developed in China since early 90's and now it plays an important role.
- However, UGS lags behind pipeline construction and is not sufficient to reply current modulation need: the share of stored gas on total consumption in China (around 4.7 bcm in 2014, 3% of consumption) is still far less than the ratio known in North America or Europe (around 20%).



Future modulation need and UGS evolution

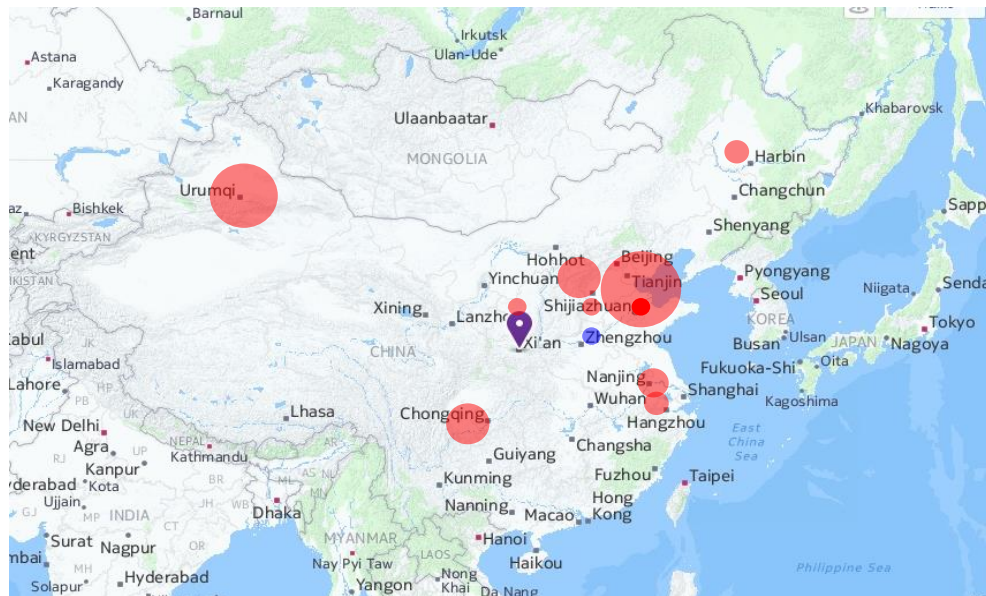
- Currently, more than 20 depleted UGS of 4.7 bcm capacity have been constructed, with part of working gas under commissioning.
- It is estimated to reach 10–13 bcm of UGS working gas capacity in 2020, while the gas storage demand (seasonal modulation and emergency reserve) in 2020 could be around 24 bcm.
- Thus, UGS in China, the major tool of gas modulation, cannot meet the current and future demand; it is important to develop rapidly more UGS capacity with good quality.

UGS types in China and its players

- Currently, the majority of developed UGS are converted from depleted oil or gas fields of Petrochina. More than ten new depleted targets are under feasibility study or constructions by Chinese giant oil & gas companies.
- There has been already a salt cavern site operated by Petrochina in Jiangsu Province, South-East China, while several caverns are still under leaching by other players in the same region. Jiangnan Region in central China, another area rich of salt resources, witnesses some other salt cavern UGS construction as well.
- Several aquifer prospects are under exploration by Petrochina in Huabei Region, North China, which is one of the key gas consumption areas.

Geographical distribution of UGS

- The depleted UGS are sometimes far from consumption regions that need more modulation tools for both seasonal and emergency peak shaving.
- Jing-Jin-Ji Region is the relatively secured by UGS while other high gas consumption regions are not accompanied by significant UGS. For example, South China is lack of UGS as there is no achievement of oil & gas exploration.



● UGS Site/Group
with size estimation

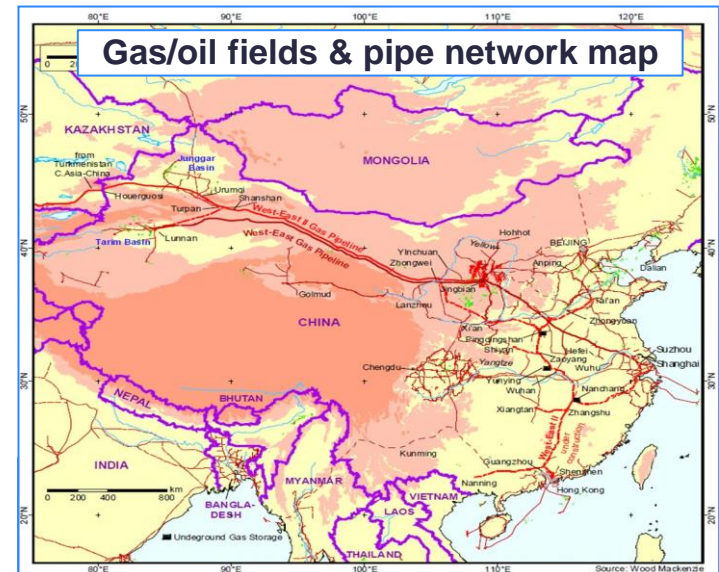
UGS Distribution in China

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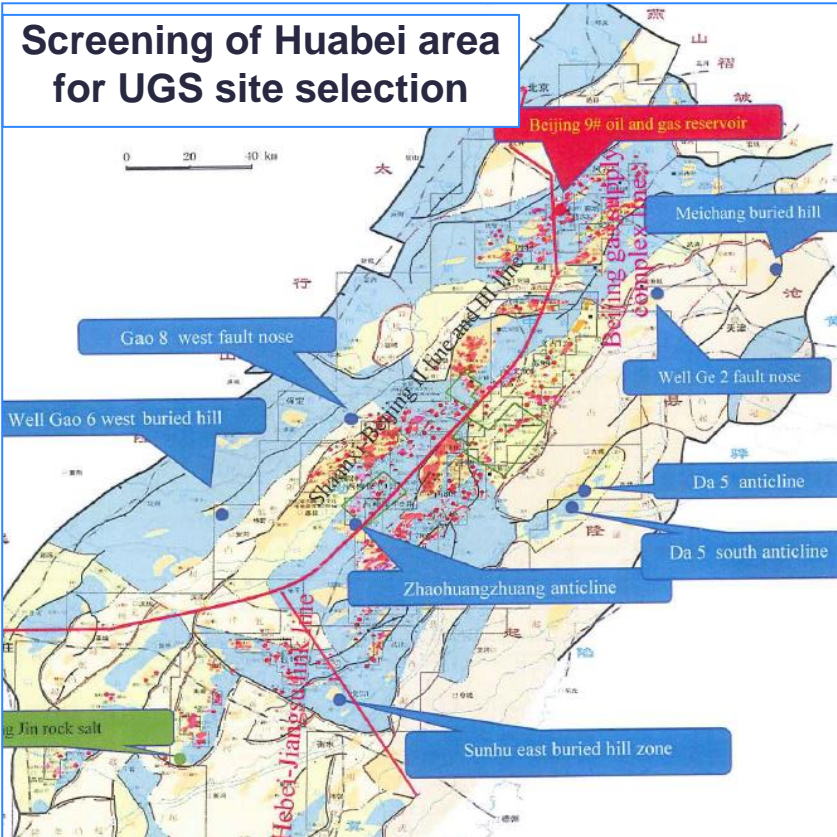
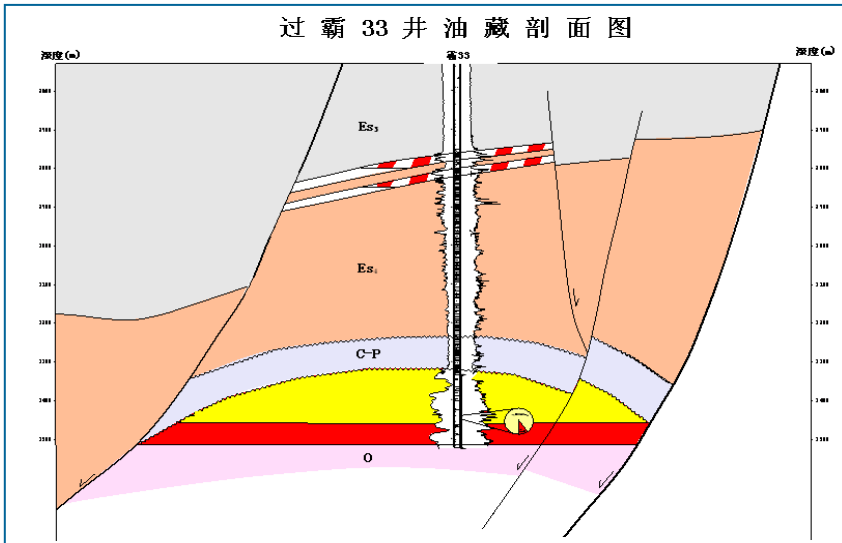
Gas supply difficulties and transportation issues

- China Gas markets are located in the eastern border far from the gas supplying areas
- China continues to invest in natural gas pipeline to link production areas in the Western and Northern areas with the demand centers along the eastern coast and to accommodate greater imports from Central and Southeast Asia
- New (unconventional) gas resources are also in areas far from domestic markets
- LNG exports impose UGS flexibility



Subsurface issues

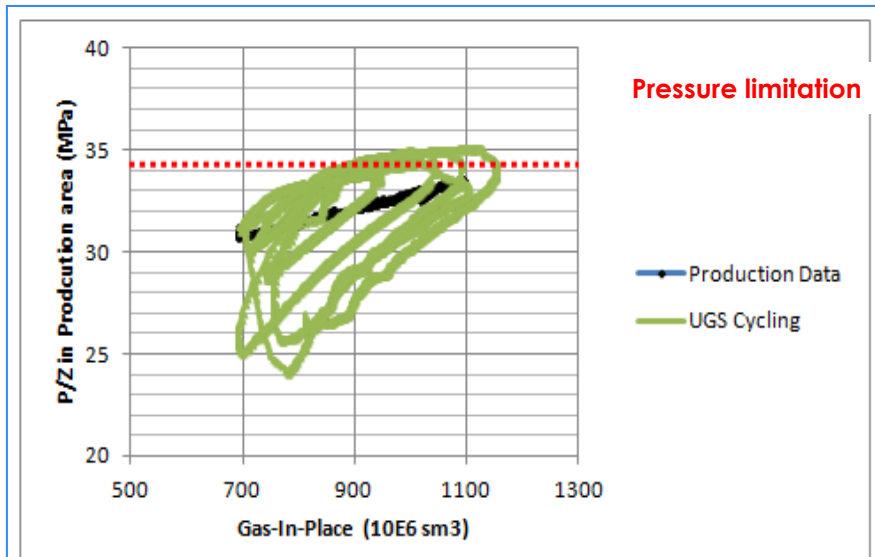
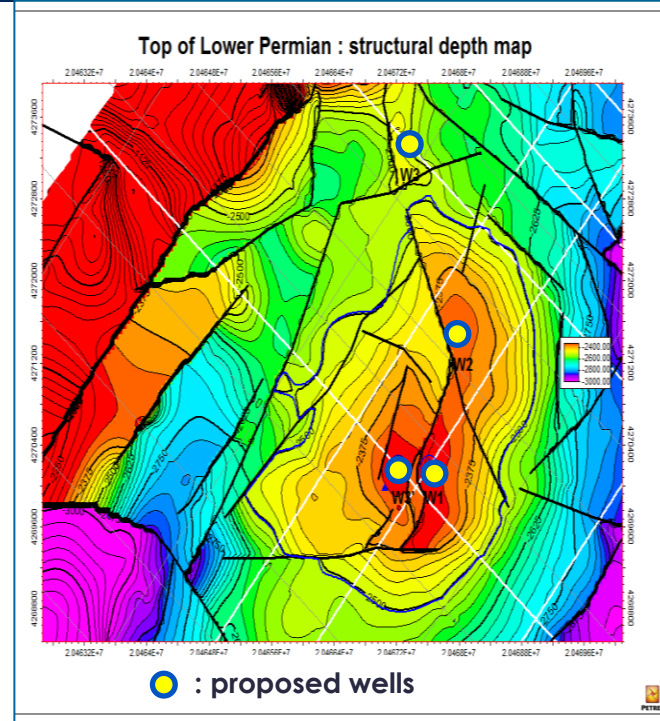
- Underground gas storages require high quality geological sites with good reservoirs at moderate depths in order to insure high gas peak-rates and to attract investors with moderate investments
- Despite exhaustive site screening studies including oil/gas depleted fields & aquifer exploration in some basins, the identified sites lead to technical challenges and make UGS development more complex than expected, especially in the eastern geological basin



Typical reservoir target characteristics
(Ordovician deep target up to 3000-4500m, low rock properties, high pressure system)

UGS need time to be operational

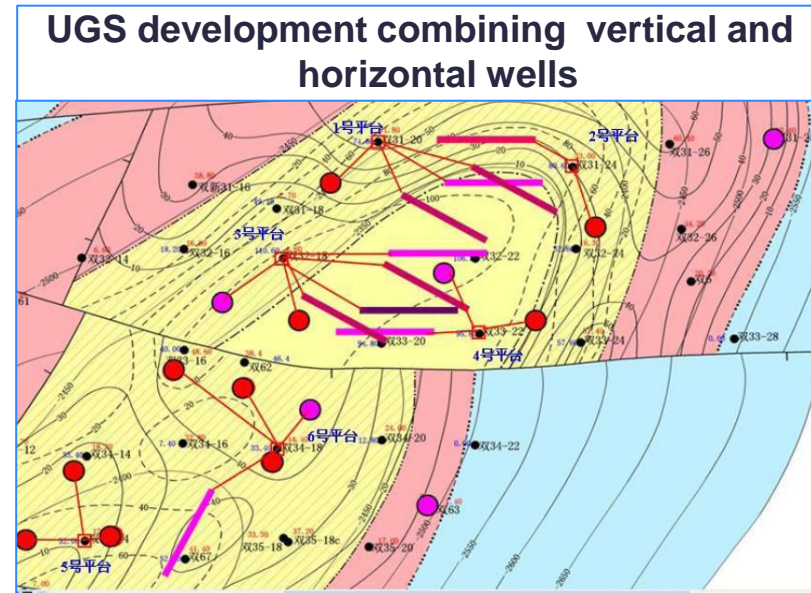
- Chinese authorities have to face with “incompressible” time constraint to build its ambitious UGS portfolio
- Moderate reservoir properties lead to long gas ramp-up to avoid any gas spill-over or excessive reservoir pressures
- Exploration of aquifer requires time for exploration & appraisal site candidates by running 3D surveys & drilling of several wells & performing many long duration well testings
- De-risking of project leads to phased development decision with initial limited capacity
- Keeping in mind from international feedback that UGS development is time and capital consuming (the most quicker facilities to develop are salt caverns & gentle depleted reservoirs : request 5 to 10 years to built)



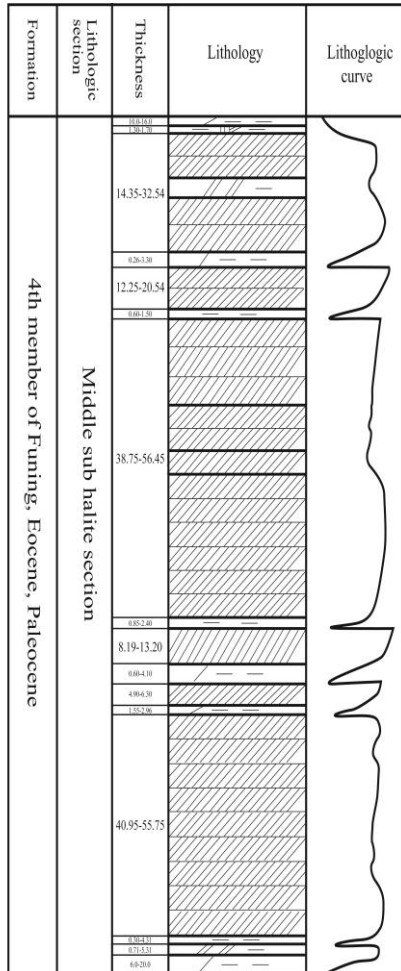
Snail plot illustrating first gas ramp-up difficulties linked to reservoir pressure increase

Additional difficulties linked to technology challenges

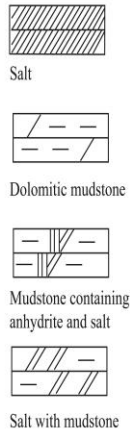
- High injection pressure is required due to active aquifers & deep reservoirs. This leads to:
 - High investment (wells, compressor, gathering system, dehydration...)
 - Excessive OPEX for fuel gas
 - High temperature variations in well (thermal stress)
 - Reservoir damage by drilling fluids (differential pressure due to highly depleted reservoir)
 - Tubular cementation more complex (presence of gas, low pressure)
- Limited well productivities encountered lead the horizontal (& deep) wells to avoid to duplicate well number
- Oil, condensate or sour gas presence to integrate to gas process plant
- Important number of former wells with seal integrity to check and possibly perform heavy Work Overs



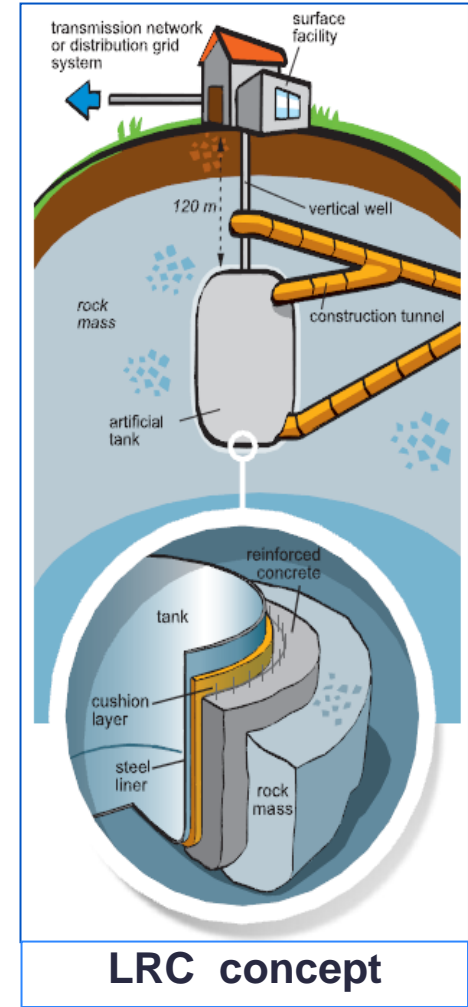
Alternative solutions are not less challenging



Jintan Lithology



- LRC (lined rock cavern) of large volume is an innovative technology but is costly and need well suited geological conditions
- Building salt caverns is limited only to few areas in China
- Both alternatives are complementary to depleted/aquifer underground gas storages because they present a limited stored volume, but can give a quick response to the market need.



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Existing UGS policies

- To date, China has not implemented a package of dedicated policies (regulation and pricing) related to UGS.
- However, some preliminary efforts have been done since recent years; National Development and Reform Commission (NDRC) and National Energy Agency (NEA) published several regulatory documents in order to promote the “marketization” of oil & gas sector, including UGS :
 - Oil & gas network, including UGS, shall respect fair opening and non-discrimination, and accept Third Party Access (TPA) if surplus capacity exists;
 - Gas distributors shall build storages for no less than 10% of the annual sales volume by 2020;
 - Two UGS are listed in the first round of infrastructure projects that are encouraged for private investment.

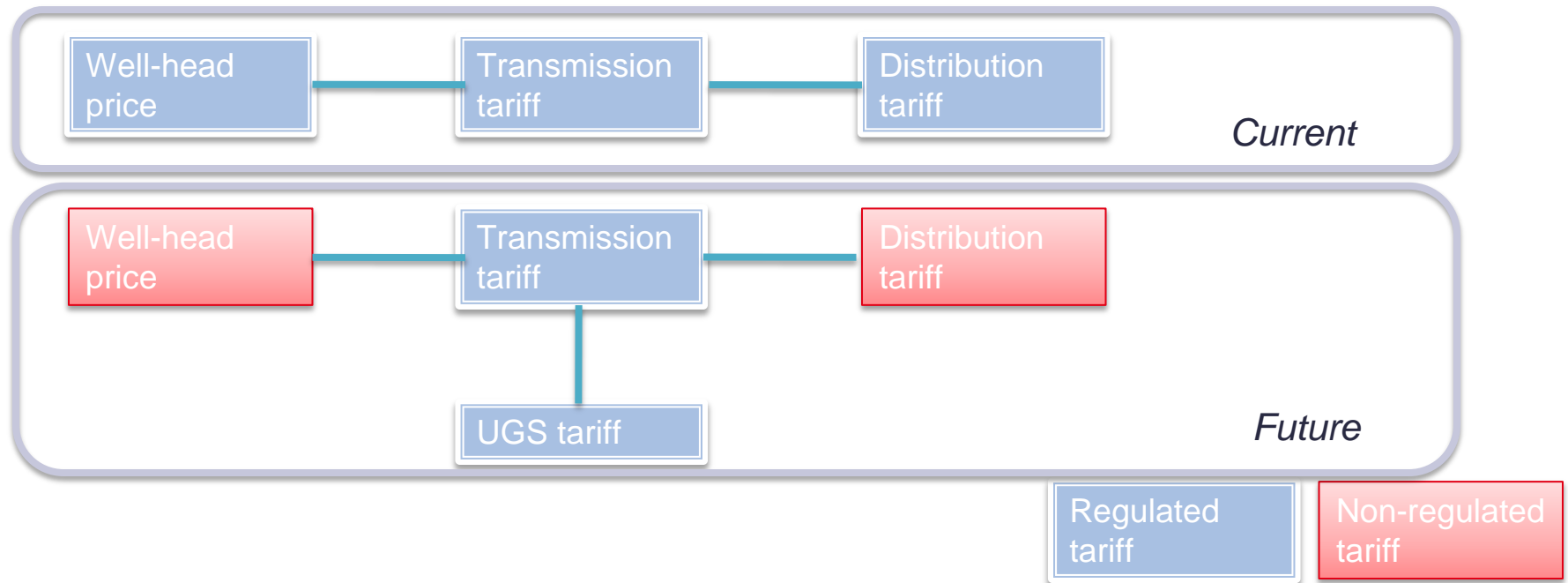
Necessity of regulation and pricing reform

- As the market needs rapid UGS development , it is important to involve private and international players to accelerate related projects. Thus, the main challenge is to build a stable system giving confidence to the investors in order to:
 - mitigate the perception of economical risks => a fair pricing system (based on cost and regulated margin) with storage obligation;
 - mitigate the technical risks => introduction of international capital associated with experiences could help certain aspects such as operating performance of low permeability reservoir, well integrity in deep reservoir and construction in multi-laminated layers.
- As China is a big and heterogeneous country, it is necessary to take a pragmatic and step-by-step approach.

Policy evolution

- According to international experiences, it could be envisaged to realize the independence of gas midstream (transmission and storage), which could encourage private capital and advanced technology being involved in further UGS development.

Possible scenario of natural gas policy (regulation & pricing) evolution



Policy evolution

- As the schema above showed, it could be a possibility that the upstream and downstream will not be regulated in the future while the midstream will be with a regulated access tariff:
 - This tariff could be calculated on the basis of cost and regulated margin;
 - This tariff is not necessarily homogenous in China as this is a big country and different UGS (near production or consumption regions) take diverse roles;
 - This tariff and its calculation method should be transparent;
 - The Third Party Access could be an option.
- Based on this, further peaking gas pricing system could be envisaged, which could then help valorize the value of flexibility created by UGS.

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Conclusion

- The development of UGS is still in its first steps in China, who will need more and more UGS as modulation capacity and should optimize their geological distribution.
- By nature and international experience, UGS developing requests lot of time (several years).
- The projects are mainly managed by the NOC of Petrochina with the assistance of the UGS centre of Petrochina Research Institute of Petroleum Exploration and Development (RIPED).
- **UGS and E&P share some technical similarities but fundamentally they are strongly different. If the gas fields are producing over 20 years, the UGS are depleted over only 90 days with very huge intake rates.**

Conclusion

- Consequently, Chinese UGS developers have to face with:
 - the lack of experience and the absence of learning curves due to the lack of injection/withdrawal histories;
 - the geological complex frameworks making the UG design complex;
 - the imposed tight UGS deployment schedule where projects are developed simultaneously penalizing the feedback experience.
- Also, in order to reach and to optimize the performance of the UGS on the long run for guarantying the profitability, specifics UGS support and operation teams would have to be created.
- Cooperation with International UGS experienced companies is one of the key success factor allowing better efficiency and saving of time.
- It is also necessary for the government to deepen the regulation and pricing reform regarding natural gas and/or UGS in order that foreign and private capital is attracted to involve into this sector and then accelerate UGS development.