

Technology and Modeling serving Customer Satisfaction

Developing a flexible offer in underground gas storage

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1. Background

European regulation and the French system

The objectives of the European regulatory framework for gas, which has evolved significantly over the past decade, has been the creation of a fully integrated internal market, on the one hand, and security of supply, on the other.

The current framework for market integration is defined by the so-called “Third Energy Package”, which includes *inter alia* Gas Directive 73/2009 and Gas Regulation 715/2009, which is based on principles of transparency and non-discrimination.

The Third Gas Directive contains a number of provisions of relevance for gas storage operators such as the requirement of legal unbundling or third party access (TPA) to storage capacity, whereas the latter can be granted on either regulated or negotiated basis. The Gas Regulation sets out direct obligations on storage system operators in the area of TPA services, transparency, capacity allocation and congestion management as well as secondary capacity market.

As regards security of supply, the new Regulation 994 adopted in 2010 seeks to ensure a coordinated approach to security of gas supply in Europe by introducing, among others, minimum EU-wide supply and infrastructure standards.

In France, the "Third Energy Package" provisions have been transposed by the Ordinance n°2011-504 of 9 May 2011. The French national law confirms the principles of transparency and non-discrimination and ensures competition of the French storage market by maintaining the negotiated access regime.

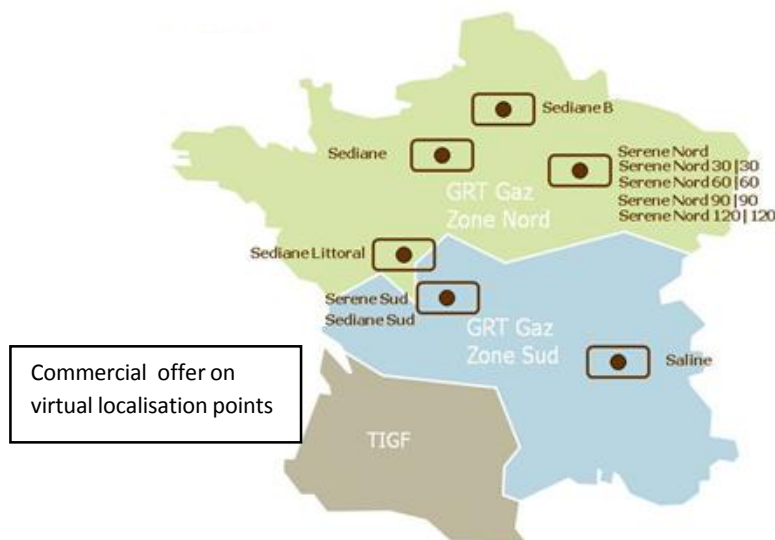
The organisation of access to storage is further defined by the specific law “storage capacity rights” : rights which are calculated annually for final customers and granted to their respective suppliers. This allows to balance seasonal gas demand and to ensure secure

supplies to customers even in bad weather conditions, such as those occurring in 1 in 50 years. This is of special relevance in France which is almost 100% reliant on external gas supplies.

Added to that, gas storage plays a complementary role providing intra-day flexibility, to adapt, in real time, the line pack needs in the gas transport system (and particularly since CCGTs appearance).

Storengy value offers

In France, gas storage capacity represents around 25% of the annual gas consumption. Yearly, Storengy's commercial offer in France is built upon grouping 13 physical storages (9 aquifers and 3 caverns and 1 depleted) in order to combine their various physical characteristics and thus creating a wider product line. This approach is based on a robust product performance in order to satisfy the customer and ensure the best performance day after day.



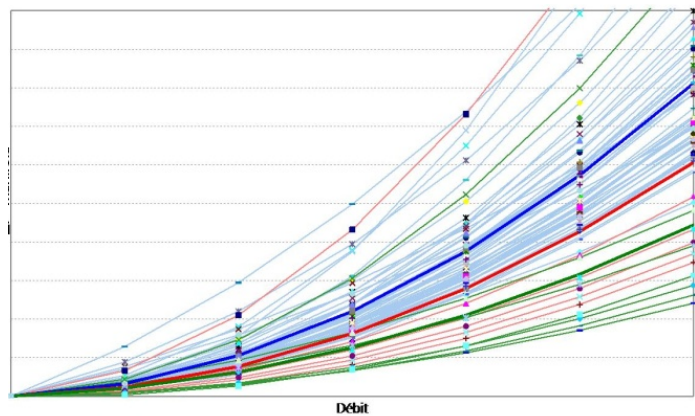
In 2011, Storengy had over 30 customers and offered 6 basic virtual storage products to the tune of 113 TWh in working gas volume. The commercial offer was enlarged with 6 more tailored made products in order to satisfy customer needs: such as injection in 30 days and withdrawal in 30 days or unbundled products. Some additional services can also be booked by the customers as additional injection or withdrawal capacity as Flow Plus product

2. Aims

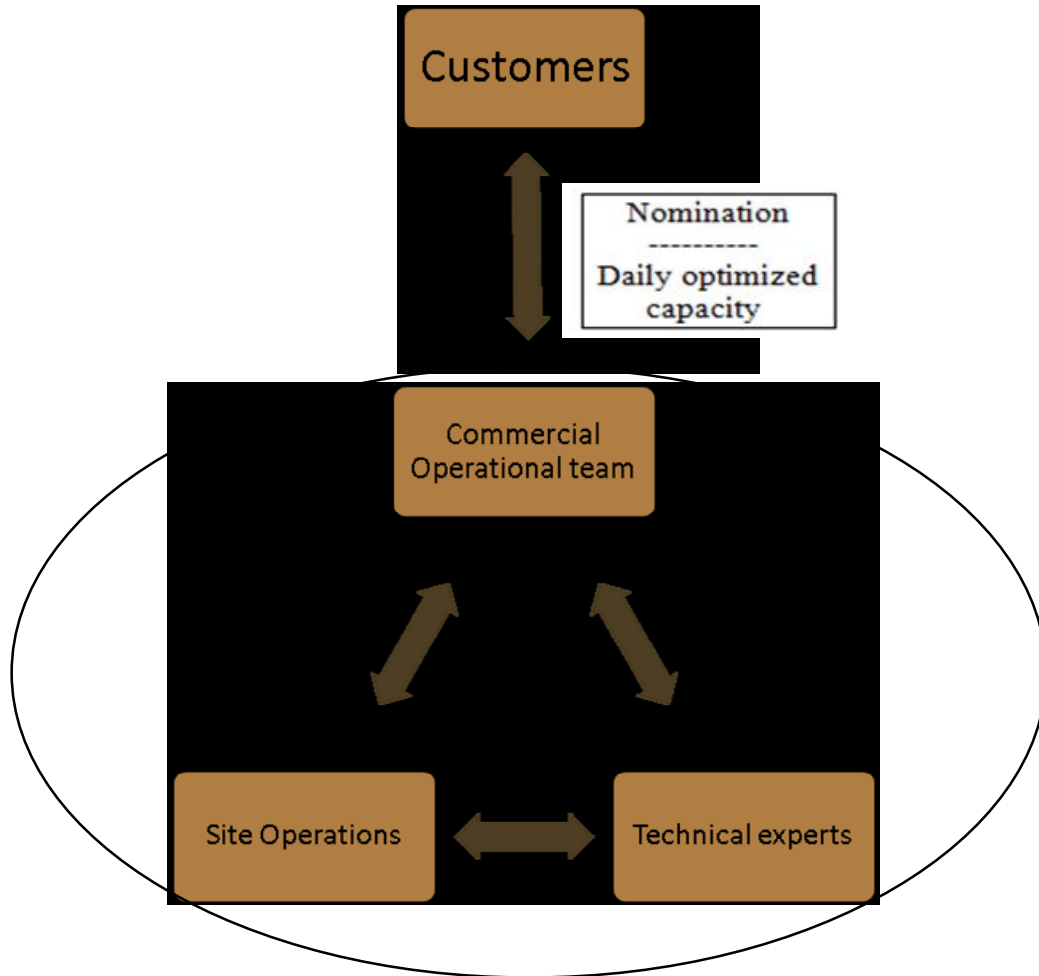
Driving the Commercial Products

Cooperation between technical and commercial teams begin on a long term basis: in one hand, historical storage movements provide information to evaluate actual available performance and in other hand, estimated short term solicitations will define future performance of each storage, and in fact, services and capacities that Storengy will offer to its customers.

Furthermore, on a daily basis, tight collaboration between site operations, commercial operational team and sub surface experts with efficient reservoir modeling ensures customers have access to available capacity. Critical hypothesis are reevaluated to control risks under specific scenarios to always be able to satisfy customers requests.



Wells performance



Daily customer demand is managed in coherence with specific site characteristics and with the entry / exit capacity to the transmission network.

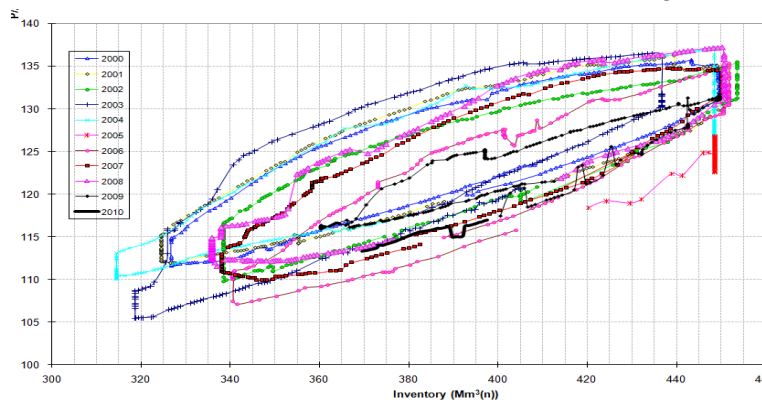
To maximize the performance of each facility and its medium term sustainability, the balance between daily movements and ideal trajectories (injection or withdrawal) is permanent. This optimization is made possible by an excellent knowledge of the subsurface (geological structure...) and surface facilities (compressor, gas treatment installation...) as well as a complete modeling of all physical phenomena related to underground storage like gas displacement mechanism in porous aquifer reservoirs or thermodynamics evolutions in salt cavern.

The interaction with Geosciences experts: a key step for adding value

Finally, the most important physical themes we deal to manage are exposed in the following table, as the technical answer we use to study each phenomena:

	Detail of risk / typical questions	Main tools of study
MAXIMUM PRESSURE RISK	<ul style="list-style-type: none"> After a limited injection in year N, what risk to reach maximum early in the following years ? => Unavailable Working space ? 	1D modeling of reservoir pressure depending on movements => Basic tool usable to study a great number of scenarios
GAS BUBBLE DEFORMATION RISK	<ul style="list-style-type: none"> Changing behavior at control wells ? Gas bubble spreading Adverse consequences in the distribution of gas between layers ? 	3D modeling of reservoir => "heavy" and complex simulation
WATER VENUE RISK	<ul style="list-style-type: none"> Increased water venues or well drowning in future years ? => Risk for the withdrawal performance in the next campaigns 	Aspect uneasy to model => Cross check of different tools: 1D, 3D and R&D approaches

Maximum pressure supervision (historical tracking on here under Hysteresis plot chart),

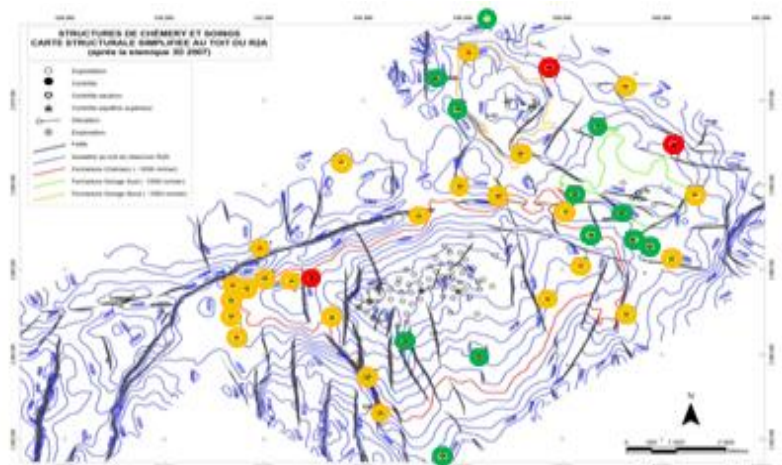


Hysteresis plot

water venue and gas bubble deformation are the main drivers to control and to maximize current and future performance of our storages.

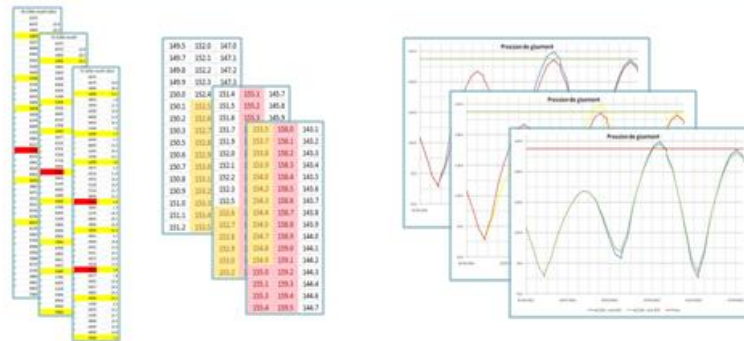
For each risk, compilation and analyze of good data is

requested. Storengy relies on the most possible in situ instrumentation as shown on this map with the well's control positioning to supervise , inter alia, gas bubble deformation.

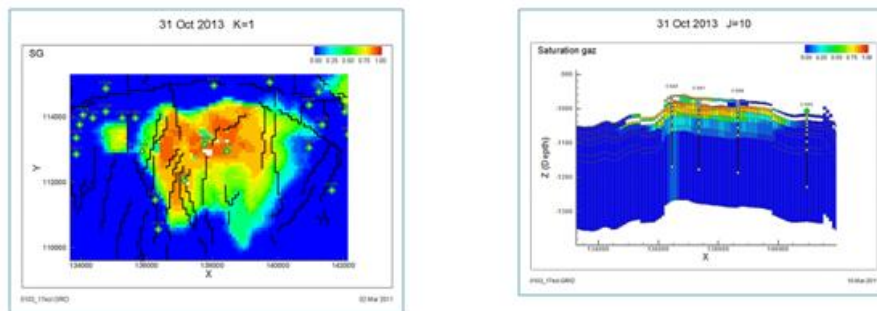


All this studies are achieved with specifics modeling from 1D to 3D tools (including home-made ones).

**Multiple scenarios simulated by 1D or 2D reservoir simulation
(pressure risk)**



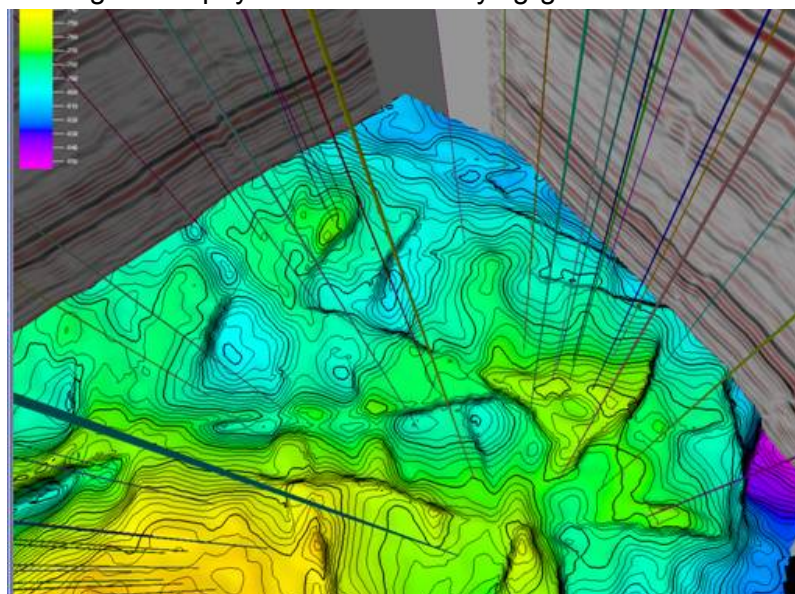
**Selected simulations are analyzed in full 3D reservoir simulation
(deformation risk)**



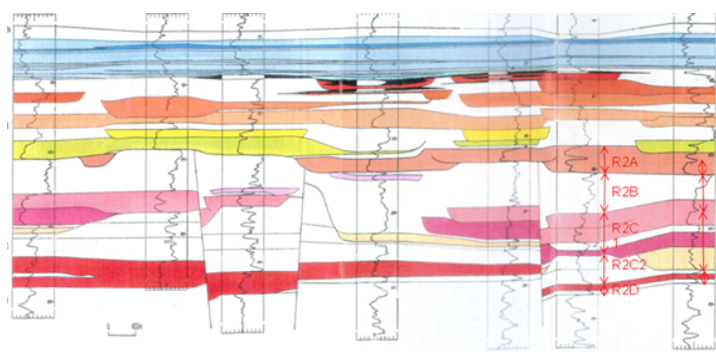
3. Methods

A sound understanding and modeling of the physics of the underlying gas and water flow in porous aquifers are needed to optimize the middle term management of a portfolio of (predominantly) porous aquifer reservoirs.

Comparing to standard depletion schemes in E&P, very complex gas and water displacement mechanisms



can occur during the storage activity due to imbibition/drainage hysteresis, specific gas trapping due to severe depletion rates (as high as 0.5 b/d), possible cross-flows, etc ..Therefore available performance (withdrawal or injection rates) is closely correlated to the reservoir and wells' past and recent production history. This can be due either to the reservoir pressure variation or to specific well behavior (notably water encroachment and sand production). The product line necessarily simplifies this physical reality for the customers.



reservoir layers and wells correlations

To tackle and better manage the associated risks and uncertainty in term of performance, either on an annual or pluri-annual scale, storage marketers and dispatchers, work in tight connection with in-house specialists in reservoir engineering and geosciences. The main objective is to take benefit from the production history to obtain the most relevant as possible numerical model which can be used afterwards to anticipate how the reservoir will perform to specific solicitations.

This is practically achieved through an integrated approach:

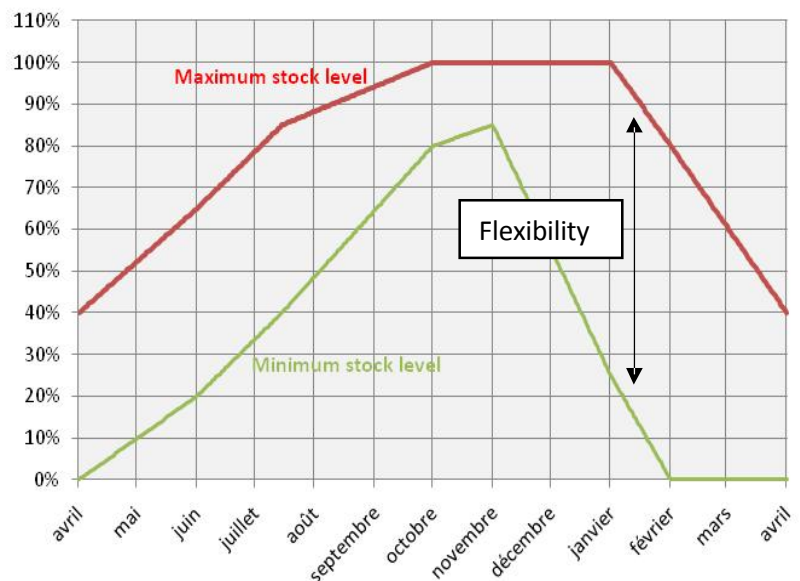
- Collection of representative data (pressure, gas/water well rates....) to match the models. The type and the frequency of these measurements are reviewed on a regular basis in order to optimize their value towards the predominant issues of each reservoir.
- Availability of adapted tools for the short, medium and long term management: various modeling tools, more or less complex, providing different perspectives, are often profitably employed for scenario analysis. 3D dynamic reservoir modeling is of course the key basis for analysis, and in-house experts have been developing, improving and maintaining for many years a dedicated and proprietary family of 3D dynamic modeling tools, tailored to the specific characteristics of aquifer storage. It also enables to have a full control on the constitutive physical laws introduced in our simulators (that may differ according to the recovery process, the displacement mode...) which is a key step to increase the quality of the history matching process and strengthen the reliability

of the forecasts in operating ranges poorly explored in the past. Additionally, complimentary tools (sometimes based on sophisticated algorithms) have been elaborated and used for dedicated purposes. It concerns various subjects like water behavior at well or reservoir level (see other WGC abstract submitted entitled “Better Water Production Forecasts for enhanced performances” for more details), optimization tools, evaluation of uncertainties.

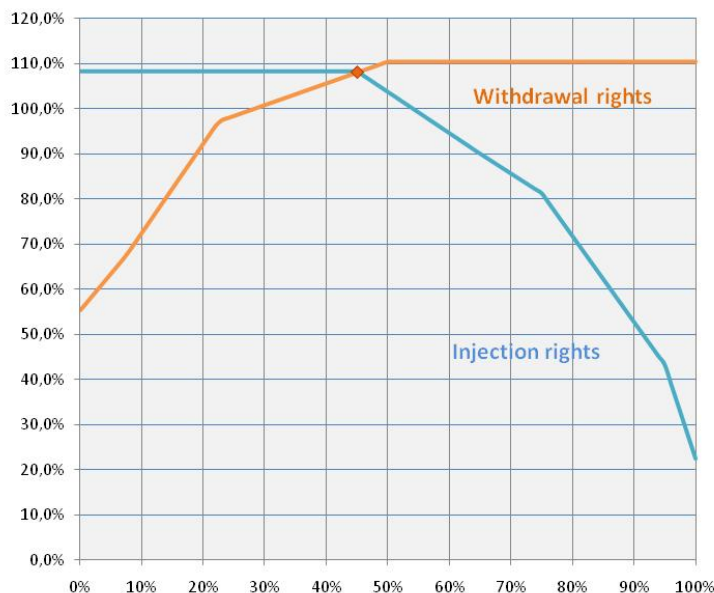
4. Results

Based on real experience, the operational commercial team provide necessary information to build commercial offer in coherence with market and customer needs. As each storage compartment is modeled, the commercial team creates, with different storages, an optimized virtual product line in order to maximize value to our clients providing them the flexibility they need.

The following charts shows all the flexibility offered through typical Storengy's commercial product based on the concerted analyze of physical capacities. First, the tunnel, with the maximum and minimum stock level authorized. Each client have to keep his own gas level between these two limits on one contractual year from April to March. Daily reachable flexibility is defined by the distance between client level and the distance to maximum or minimum limit.



Second, this flexibility is fully available with daily contractual capacity rights, as well in injection or withdrawal, in line with storages physical capacity on which the commercial offer is based. As shown on the left chart:



correlation between movement capacity rights and gas storage level. The more you fill in your storage capacity, the more you have withdrawal rights and the less you can still inject.

5. Conclusions

Specific computer tools, following simultaneously real time customer demand and physical movements, provide a reliable and flexible solution while guaranteeing optimized storage site exploitation. These tools, still with technical expert input, allow behavior simulation to anticipate and understand the risk of performance degradation of the facility. As a result, commercial strategies and operational variation are tightly linked. This know-how methodology enables Storengy to perform the creation and/or the adaptation of a wider product line. And to build virtual reliable and flexible storage capacity commercial offers in France as to satisfy customers' needs and guarantee the access to booked capacities.