

Underground gas storage

ENERGY storage of the future



Good reasons for gas

Natural gas is the ideal match for renewables

There is no way of saving up wind and sunlight, but natural gas can be stored. That means it can be used to even out the unavoidable fluctuations in renewable energy output. This applies to homes, where gas can heat water when the sun doesn't shine, and it also applies to public power supplies. The wide swings in renewable electricity feed-in to the grid call for complementary technologies that are able to respond quickly and flexibly to supply shortfalls. In short, natural gas is opening the way for the renewable energy age. It is the natural partner for renewables.

Natural gas is climate friendly

Natural gas is the conventional energy source with the best climate performance. It releases 25 % less greenhouse gases than oil, and 30 – 35 % less than coal when burnt, and it is virtually dust free. Gas already plays a big part in keeping down emissions. Transportation in safe underground pipelines significantly reduces environmental impacts as compared to competing energy sources. Fortunately, the world has vast natural gas reserves, and in the longer term it will also be possible to manufacture gas from renewable energy sources.

Natural gas is highly efficient and economical

Modern domestic condensing boilers have efficiencies as high as 98 %, and natural gas is also an excellent fuel for power generation. Combined-cycle gas and steam turbine generating stations are among the most efficient conventional power plants. In combined heat and power configurations they deliver efficiencies of over 90 %.

Natural gas is safe

From the field development stage through to transportation, storage, and use to generate heat and power, natural gas is a model of safety.

Natural gas is the key to supply security

Natural gas plays a key role in Austrian and European security of energy supply. Austria's gas comes from domestic production and imports under long-term contracts with reliable partners across Europe. Austria has a well-developed pipeline grid, and due to its geographical location, it is connected to all of the major transit systems in the European grid.



The company

RAG Austria AG is Austria's largest gas storage company – making it the country's biggest energy storage provider – and one of Europe's leading technical storage facility operators. The company develops pioneering energy technologies that act as partners to renewables. Its portfolio of business activities also includes gas production, supply and trading, as well as the use of gas as a transport fuel.

A decarbonised future will require massive, seasonally flexible energy storage capacity. All this is provided by RAG.

RAG Austria AG is playing a vital role in achieving Austria's ambitious climate goals, and in the sustainable stewardship of the country's raw material and energy supplies. Without the energy in RAG's storage facilities, phased decarbonisation would not be possible, so they are key to future energy security. RAG Austria AG is committed to maximising quality and maintaining its strong long-term commercial performance by leveraging its longstanding subsurface engineering expertise, wide-ranging technological capabilities,

high environmental and safety standards, and collaborative and transparent corporate culture. The company's success reflects its ability to innovate, and to spot and capitalise on new trends and business opportunities. RAG's goal is to provide its customers with safe, efficient, environmentally friendly and affordable energy and gas storage services – sustainably and responsibly.



Gas – the energy carrier of the future

Providing secure, sustainable, competitive and affordable energy for all is a major challenge, and is essential to economic growth and prosperity in Europe.

In contrast to electricity, gas can be stored securely and transported over very large distances without losses, out of sight, in a well-established underground transmission network.

Conserving resources, boosting efficiency, enhancing storability, reducing dependency on imports and expanding the use of domestic energy sources are central issues for Europe's energy sector – and we must pay close attention to them.

The global energy business is in a ferment of change. It is on course for a sustainable energy system that will limit climate change. The challenges faced globally and in Europe are immense.

Security of supply, as well as efficiency and affordability, must be delivered along with decarbonisation and the move to green technology. This can only be achieved by a huge collective effort, for which the EU's Energy Union strategy and the 2015 UN Climate Change Conference in Paris have laid the groundwork.

Rethinking gas. For RAG, focusing on gas, an energy carrier that is highly versatile and promising, means looking at it from a new perspective.

Conventional natural gas, which will continue to play an indispensable role in energy supplies, is only one aspect of this. The other is "green gas" – biogas (or biomethane)

made from waste materials, and synthetic gas produced using power-to-gas technology. The Underground Sun Storage and Underground Sun Conversion projects developed by RAG have opened up the unique proposition of storing large volumes of gas produced from renewable sources – such as solar and wind power (synthetic methane and hydrogen) – seasonally and carbon-neutrally underground for withdrawal whenever they are needed.

This turns RAG's gas storage facilities into energy storage facilities, creating a link between the gas and electricity sectors so that they work together still more closely..

Gas already has a broad range of applications, underpinning safe, efficient and sustainable energy supplies. It is used to generate electricity and heat, and in transportation as Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG).

"Gas is a guarantor of secure, sustainable, affordable and competitive energy supplies. These four factors are the keys to the success of the energy transformation."

Gas storage facilities – the energy storehouses of the future

Gas storage facilities underpin Europe's energy supplies. Natural gas storage has grown in importance in recent years, and is now pivotal to security of energy supply in Austria and Europe as a whole.

RAG is working on new projects in Austria and abroad aimed at meeting the growing demand for storage capacity, to ensure that eco-friendly natural gas is available whenever it is needed. For over 30 years, RAG has been using depleted gas reservoirs to store gas, playing a key role in security of supply. Today it is Europe's fourth largest storage operators, after converting about half of the gas reservoirs discovered over its 80-year history into sustainable storage facilities. This is a figure unmatched anywhere in the world. By progressively expanding its storage capacity, RAG has added a key additional link to its supply chain, and in so doing it has developed a sustainable form of gas production.

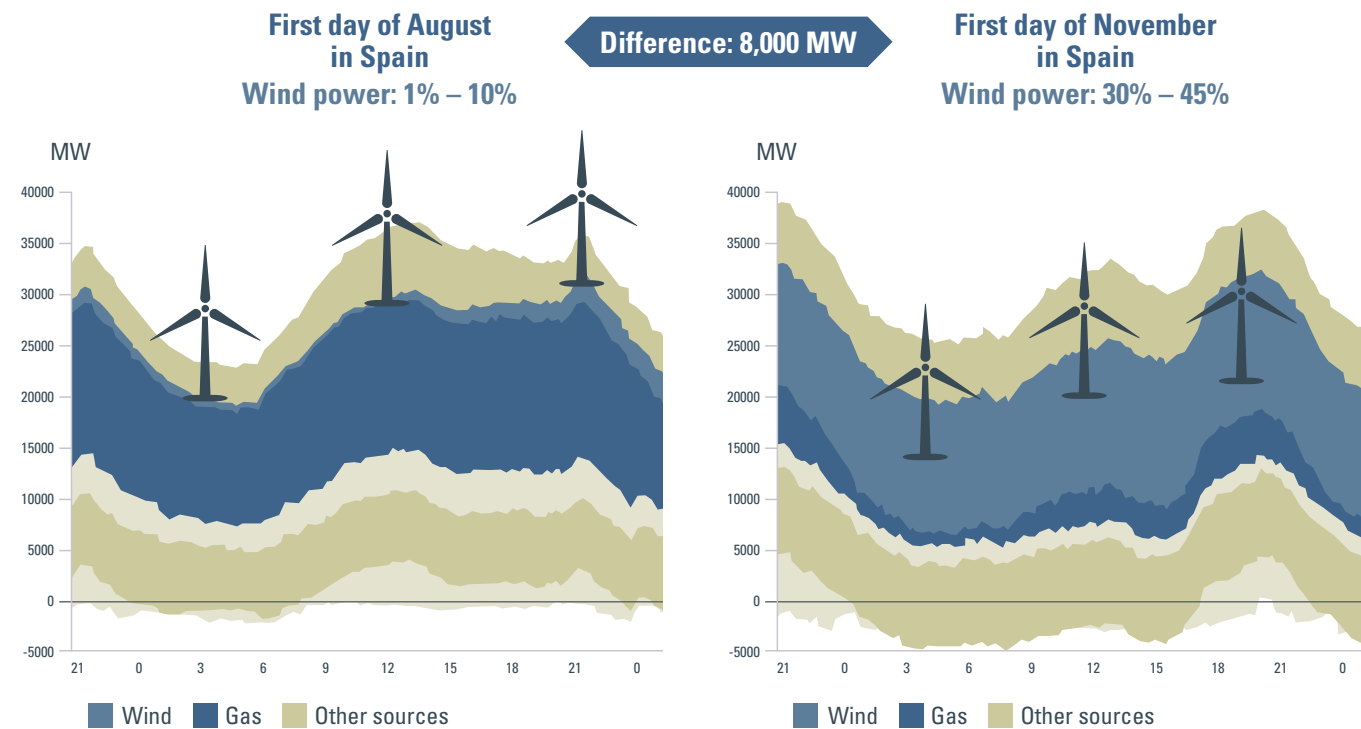
Meanwhile, after the completion of the second development phase of the 7Fields storage facility in April 2015 at Oberkling and Pfaffstätt, RAG's gas storage capacity expanded to around 6 billion cubic metres.

The company's storage facilities serve customers in Austria and abroad, and include joint ventures with major multinationals such as Gazprom and Uniper.



Role of storage facilities

Balancing out daily swings



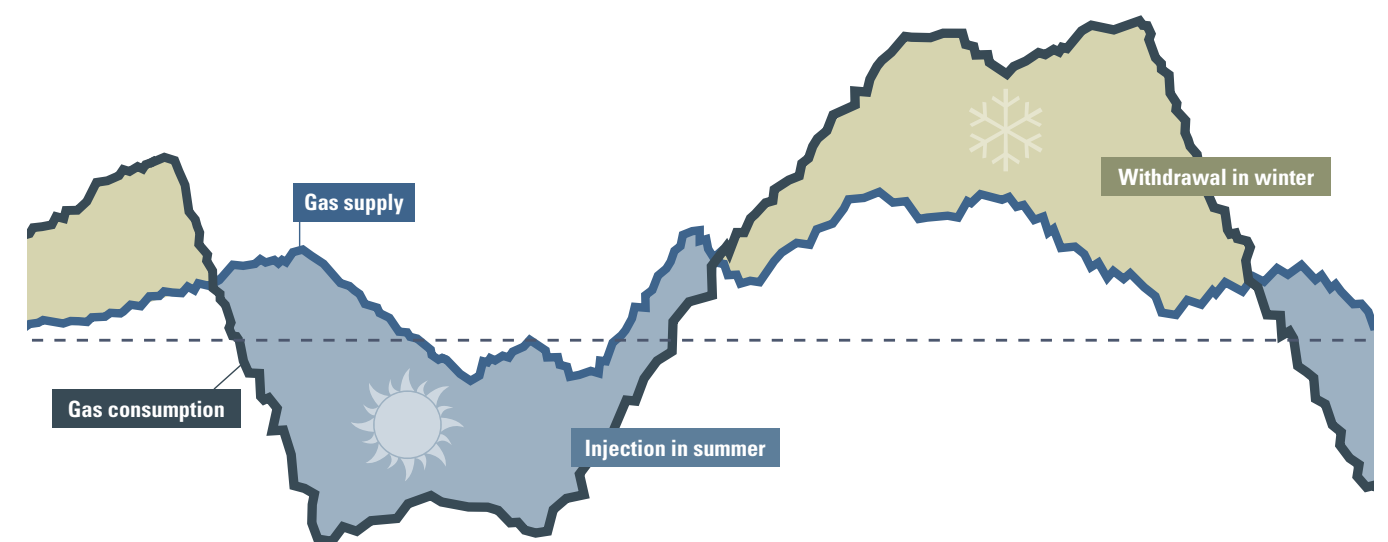
Balancing out daily and seasonal demand swings

Natural gas is produced throughout the year, at roughly constant rates. Austria's imports are transported along long-distance pipelines from Norway and Siberia, and as LNG cargoes. The amount of gas consumed by industry, power stations and households varies according to the season and time of day. Demand is much higher in winter than in summer, and more gas is used during the day than at night. Gas must be stored to balance out these swings in demand, and to ensure that it is available when needed.

Did you know that you, too, benefit significantly from RAG's storage services?

Demand-oriented storage and withdrawal of natural gas stored in the reservoir can ensure that every consumer, from industrial customers to individual households, can be supplied safely, environmentally friendly and reliably with energy at all times.

Balancing out seasonal swings



Gas storage – the perfect partner for renewables

RAG's gas storage facilities are crucial to the progressive decarbonisation of the energy system, the attainment of climate targets and the growing use of renewable energy sources. Together, environmentally friendly natural gas and renewables are a dream team. Natural gas from storage is a dependable source of energy to balance out the swings in wind and solar power output. To achieve the planned expansion in the use of renewables, these

energy sources need a partner in the energy mix to even out the supply fluctuations – and natural gas fits the bill perfectly. It is easy to store, and gas-fired power stations are not only environmentally friendly and efficient, they also offer outstanding operating flexibility. They are able to react immediately to ups and downs in wind and solar output.

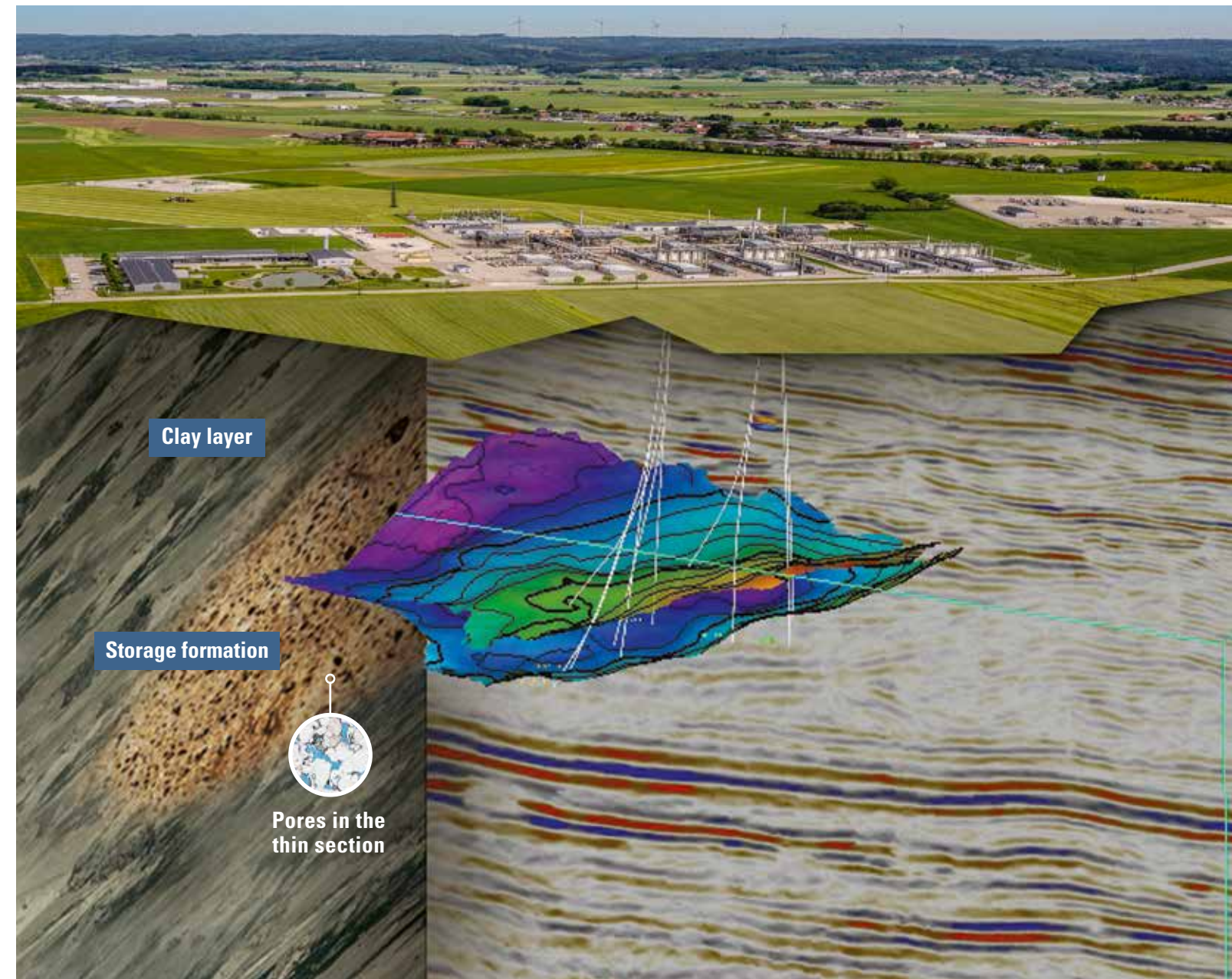
What is an underground gas storage facility?

Storing gas in depleted reservoirs is certainly one of the most efficient, eco-friendly and safe ways of stockpiling energy – but it takes a lot of expertise to get it right. A modern storage facility is a masterpiece of engineering. RAG's extensive gas storage experience has enabled it to hone its skills in this area. Our state-of-the-art technology makes our facilities highly flexible and safe.

From gas fields into storage facilities

Austria has geological structures that are unique in Europe and ideal for gas storage. New supplies can be stored in these formations, where gas accumulated naturally over millions of years, at depths of over 1,000 metres. These former gas fields originated over 20 million years ago, when organic matter in the primeval ocean that occupied today's Prealps was trapped by sandstone sediments. Over time, the gas migrated into the pores of the sandstone, forming gas reservoirs that can have an area of several square kilometres. Clay strata several hundred metres thick overlie the gas reservoirs, and this natural insulating layer makes them an extremely safe means

of underground storage. The proof of this comes from nature itself, since the original gas reserves were held there for millions of years. RAG converts gas reservoirs into storage facilities when most of the gas has been extracted. Gas is fed into the reservoirs and withdrawn from them via wells when needed. Surface installations are also required. These include compressors to inject and withdraw the gas under pressure, and equipment to dry and clean it before sending it on its way to consumers. All these process units have been tried and tested over several decades, and are continuously improved. RAG's storage expertise makes a major contribution to gas supply security in Austria and Central Europe as a whole.



„After starting out more than 30 years ago with 40 million cubic metres of storage capacity in Puchkirchen, today we are the fourth-largest storage operator in Europe. We have a wealth of experience, and state of the art storage facilities around six billion cubic metres of capacity – more than a hundredfold increase from our modest beginnings. We continue optimizing consequently our storage operation and are stepping up our R&D effort regarding energy storage.“

How do gas storage facilities work?

01 Public grid

When gas arrives at a storage facility via a pipeline network, it first enters a metering station where it is filtered, and the quantity and quality are measured. Injection and withdrawal take place via a number of wells. Where necessary, compressors bring the incoming gas up to the right injection pressure. Since compression raises the temperature, the gas must then be cooled before being conveyed to the wellhead and injected via the probes into the natural rock formations. The pressure that originally prevailed in the reservoir is not exceeded.

02 Metering station

03 Compressor station

04 Cooling units

A certain amount of natural gas is left as cushion gas in the reservoir to minimize the number of wells. The cushion gas assists the pressure released after the natural gas has been exhausted and optimizes the storage facility for operation. The so-called „working“ gas is injected and withdrawn as needed. In this way, the natural gas storage can be operated economically and ecologically at the highest level.

05 Wellhead

06 Well

07 Reservoir

The gas is withdrawn when it is needed, and processed accordingly. It must be dried as it will have absorbed moisture in the reservoir. Once it is on-specification it enters the public grid and is transported to the consumer.

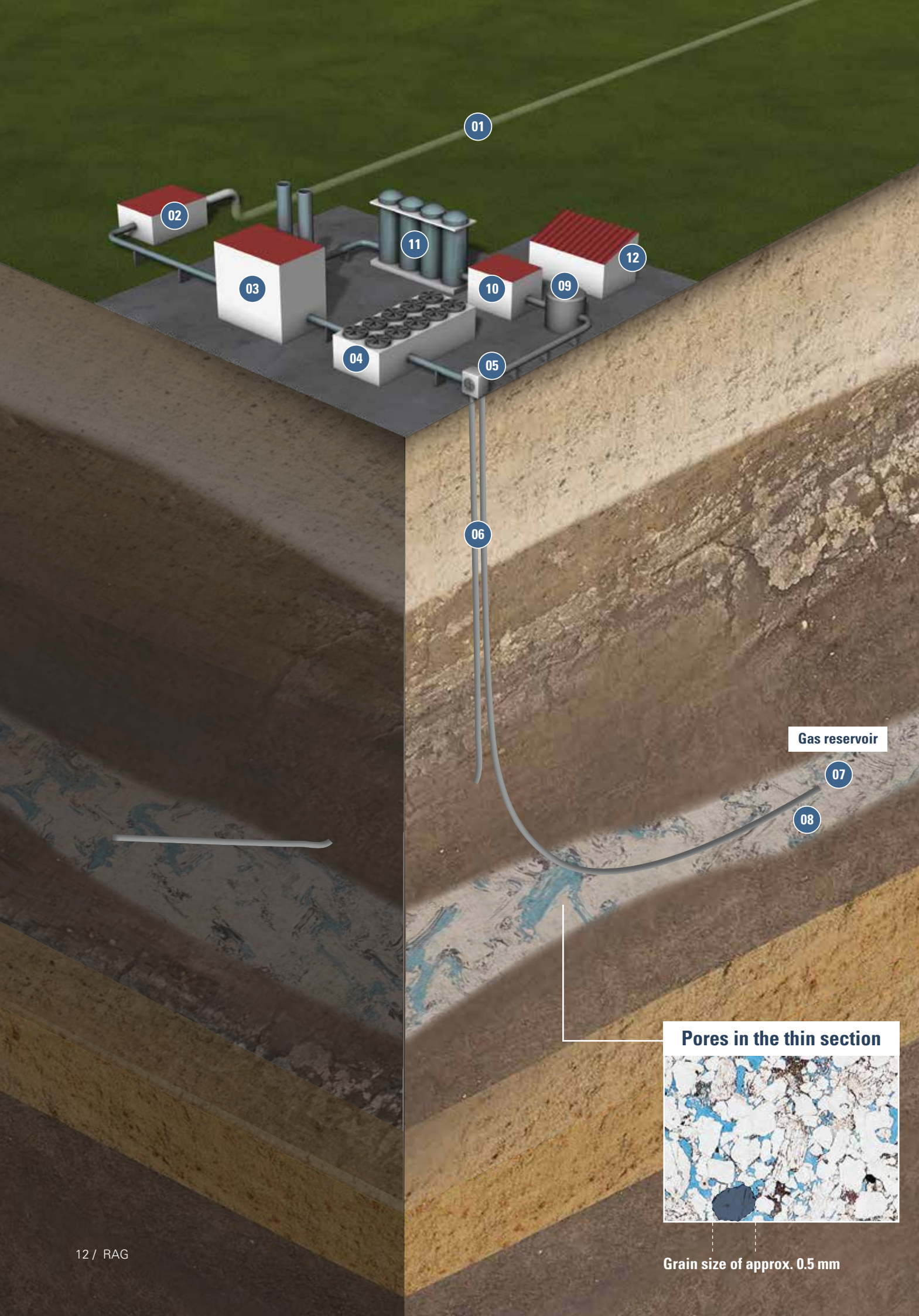
08 Working or cushion gas

09 Preheater

10 Pressure reduction station

11 Drying unit

12 Control room and stores



RAG’s gas storage facilities

Puchkirchen/Haag

RAG’s gas storage operations originated in Puchkirchen, Upper Austria. This was the site of its first Austrian natural gas discovery, made in 1956. In 1982, after more than 25 years’ production, RAG began using the gas reservoir as a storage facility. The last of a number of expansions was completed in 2009, and in the summer of that year Puchkirchen was linked with the Haag facility by a 20-kilometre pipeline. The facility currently has a maximum working gas volume of about 1.1 bn cu m (equivalent to 12.2 terawatt hours, TWh), and injection and withdrawal capacity of 520,000 cu m/hour (5.9 gigawatts, GW).

2018 performance indicators (TWh, GW and MW thermal)			
Reservoir area	6 x 2 km / 5 x 2 km		
Reservoir depth	1,100 m / 1,000 m		
Working gas volume	12.2 TWh	1,100 mn cu m	
Max. withdrawal capacity	5.9 GW	520,000 cu m/h	
Max. injection capacity	5.9 GW	520,000 cu m/h	

Aigelsbrunn

Gas production at this field started in 2001. Development of the gas storage facility began in 2008, and it was commissioned on 1 April 2011. Aigelsbrunn has a maximum working gas volume of approximately 130 mn cu m, and injection and withdrawal capacity of 50,000 cu m/hour (equivalent to 565 MW).

2018 performance indicators (TWh, GW and MW thermal)			
Reservoir area	1.5 x 1 km		
Reservoir depth	1,350 m		
Working gas volume	1.5 TWh	130 mn cu m	
Max. withdrawal capacity	565 MW	50,000 cu m/h	
Max. injection capacity	565 MW	50,000 cu m/h	

Haidach 5

The repurposing of the depleted gas formation as a storage reservoir was carried out in 2005. Haidach 5 has a maximum working gas volume of around 16 mn cu m (equivalent to 181 gigawatt hours, GWh), and injection and withdrawal capacity of some 20,000 cu m/hour (226 megawatts, MW).

2018 performance indicators (TWh, GW and MW thermal)			
Reservoir area	0.5 x 1 km		
Reservoir depth	1,450 m		
Working gas volume	181 GWh	16 mn cu m	
Max. withdrawal capacity	226 MW	20,000 cu m/h	
Max. injection capacity	226 MW	20,000 cu m/h	

Nussdorf/Zagling

RAG built this facility between 2011 and 2014, as part of the 7Fields project, and it was commissioned in April 2014. It has a working gas volume of 289 mn cu m (equivalent to 3.3 TWh), with an injection capacity of 120,200 cu m/hour (1.4 GW) and withdrawal capacity of 150,000 cu m/h (1.7 GW).

2018 performance indicators (TWh, GW and MW thermal)			
Reservoir area	7 x 1,6 km / 2 x 2 km		
Reservoir depth	1,470 m / 1,351 m		
Working gas volume	3.3 TWh	289 mn cu m	
Max. withdrawal capacity	1.7 GW	150,000 cu m/h	
Max. injection capacity	1.4 GW	120,200 cu m/h	

Capacity at these four storage sites is marketed by RAG’s wholly-owned subsidiary RAG Energy Storage GmbH. www.rag-energy-storage.at



Joint Venture gas storage facilities



Haidach

The Haidach gas storage facility is a joint venture between RAG, Russia’s Gazprom Export and Germany’s Wingas. RAG designed and built the facility, and operates it. Gazprom markets the capacity. The first development phase came onstream in 2007, and the second in April 2011. The total storage capacity of 2.78 bn cu m of natural gas is equivalent to a quarter of annual gas consumption in Austria. Haidach is the second-largest storage facility in Central Europe.

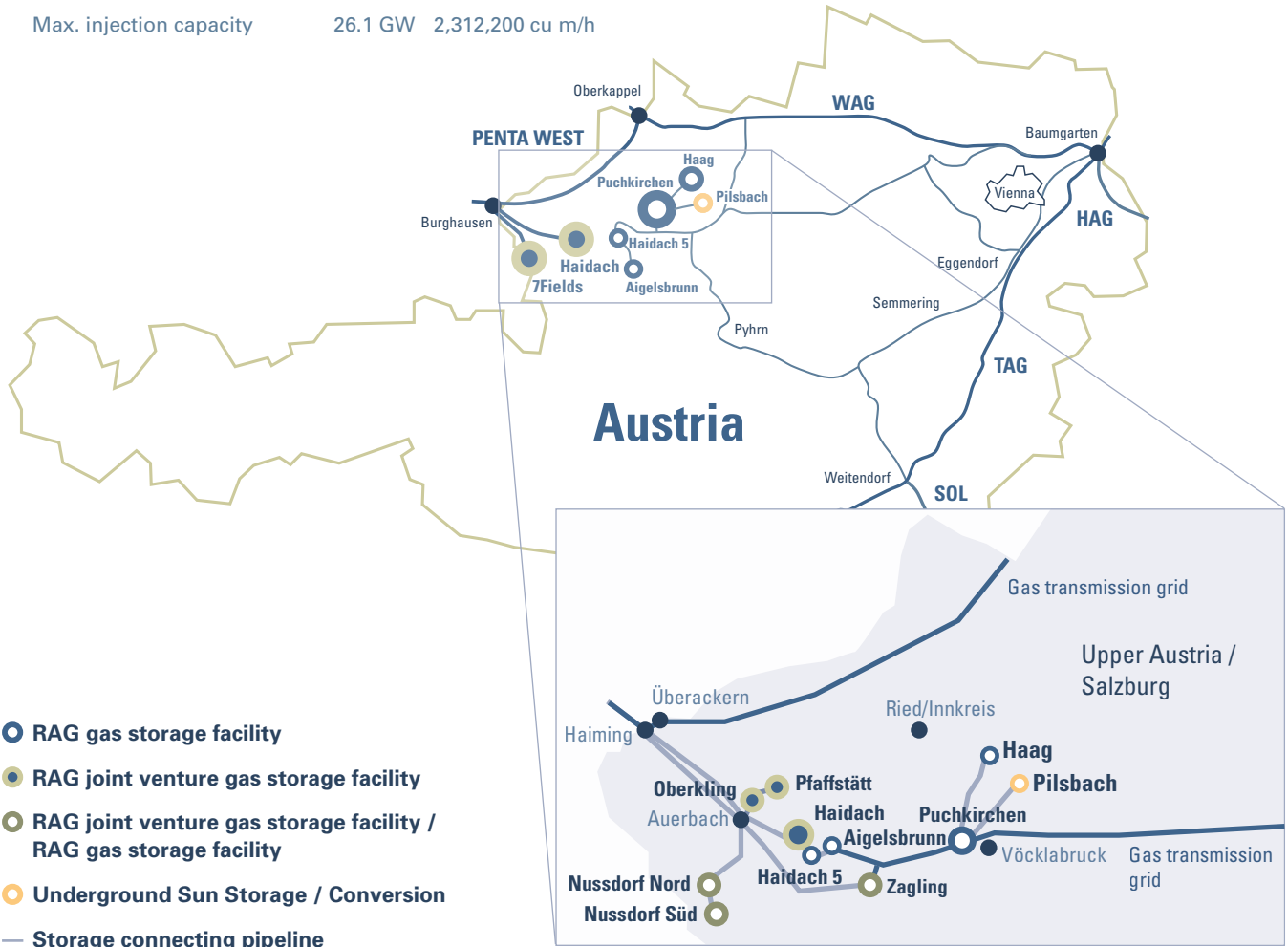
2018 performance indicators (TWh, GW and MW thermal)			
Reservoir area	3.5 x 5 km		
Reservoir depth	1,600 m		
Working gas volume	31.4 TWh	2,780 mn cu m	
Max. withdrawal capacity	13.1 GW	1.2 mn cu m/h	
Max. injection capacity	11.3 GW	1.0 mn cu m/h	

Total storage capacity 2018 (TWh, GW, MW ... thermisch)		
Working gas volume	68.1 TWh	6,028 mn cu m
Max. withdrawal capacity	31.7 GW	2,803,000 cu m/h
Max. injection capacity	26.1 GW	2,312,200 cu m/h

7Fields

The 7Fields facility is a joint venture project between RAG and Germany’s Uniper. As with Haidach, RAG was responsible for design and construction, and operates the facility. Uniper markets the capacity. The first development phase was completed in April 2011, after just two years’ construction time, and the second phase was finished in April 2014. Storage capacity now totals some 1.7 bn cu m. The site is unique in Europe, with four storage stations connected via pipelines to three metering stations, and to the Austrian and international gas grids.

2018 performance indicators (TWh, GW and MW thermal)		
Reservoir depth	1,300 to 2,300 m	
Working gas volume	19.6 TWh	1,733 mn cu m
Max. withdrawal capacity	10.2 GW	903,000 cu m/h
Max. injection capacity	6.8 GW	602,000 cu m/h



The highest safety and environmental standards

Providing environmentally friendly, safe and affordable energy for the future is RAG's prime objective and its greatest challenge.

The steady rise in global energy demand means that responsible use of the valuable energy resources at our disposal, environmental protection and gaining acceptance as a good neighbour are more important than ever. Sustainable, safe operations geared towards benefiting both society and the environment are our top priority. RAG has a long track record of shouldering its responsibilities all along the value chain – an approach that underpins all of our activities and lies at the heart of our success.

Top technical expertise and certified safety procedures

RAG has demonstrated that it is equal to the technical challenges posed by gas storage. Its state-of-the-art storage facilities are permanently monitored and maintained. Highly skilled staff run the facilities from the dispatching centre, working around the clock to maximise efficiency, and optimise environmental and technical performance. RAG is also an industry leader in terms of safety. The entire safety management system at RAG's facilities is based on audited processes.

In September 2009 RAG became the first European company to obtain Technisches Sicherheitsmanagement (TSM) certification from the German Vereinigung des Gas- und Wasserfaches e.V. (Technical and Scientific Association for Gas and Water). A surveillance audit carried out in 2014 did not give rise to any objections. Systematic quality and environmental management and strict health and safety standards are central to the company's philosophy.



Conserving resources, protecting the environment and using energy efficiently

Husbanding natural resources and good environmental stewardship play a vital role in gas storage, and all the processes at RAG's storage facilities are designed for high levels of environmental soundness. Minimising energy use and emissions, preventing waste, and using cutting-edge technology to monitor the company's plant and pipelines are particularly important. RAG introduced an internal control system for its storage operations in 2011, meaning that it began systematically collecting, analysing and interpreting all energy-related data. This information feeds into energy saving programmes. In 2013 we implemented an energy management system based on the ÖNORM EN ISO 50001:2011 standard, so as to enable our approach to be externally audited and certified. These initiatives have allowed us to continuously improve our energy use and reduce the related emissions, and to fulfil the legal requirements imposed by the Federal Energy Efficiency Act, which transposes the EU Energy Efficiency Directive (2012/27/EU).

A good neighbour and a good listener

Being a good neighbour will be critical to maintaining sustainable energy supplies in the future. Responsible treatment of all stakeholders, especially local residents in the areas where we operate, has always been an article of faith for RAG. That is why we constantly strive to engage stakeholders in an active and open dialogue. We see ongoing communication with local authorities, public agencies and key local institutions as particularly crucial to productive partnerships. Partnerships and open days help to demonstrate the strength of our commitment to the regions where we operate. RAG's activities also promote regional economic growth, and as a major employer, the company makes an important contribution to the Austrian economy.



RAG Austria AG

Schwarzenbergplatz 16

1015 Vienna, Austria

office@rag-austria.at

www.rag-austria.at

Legal information

Published by RAG Austria AG, Schwarzenbergplatz 16, 1015 Vienna

Pictures: RAG archives, steve.haider.com, Karin Lohberger Photography and fotolia.de

Last updated: September 2018

