



Underground gas storage

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

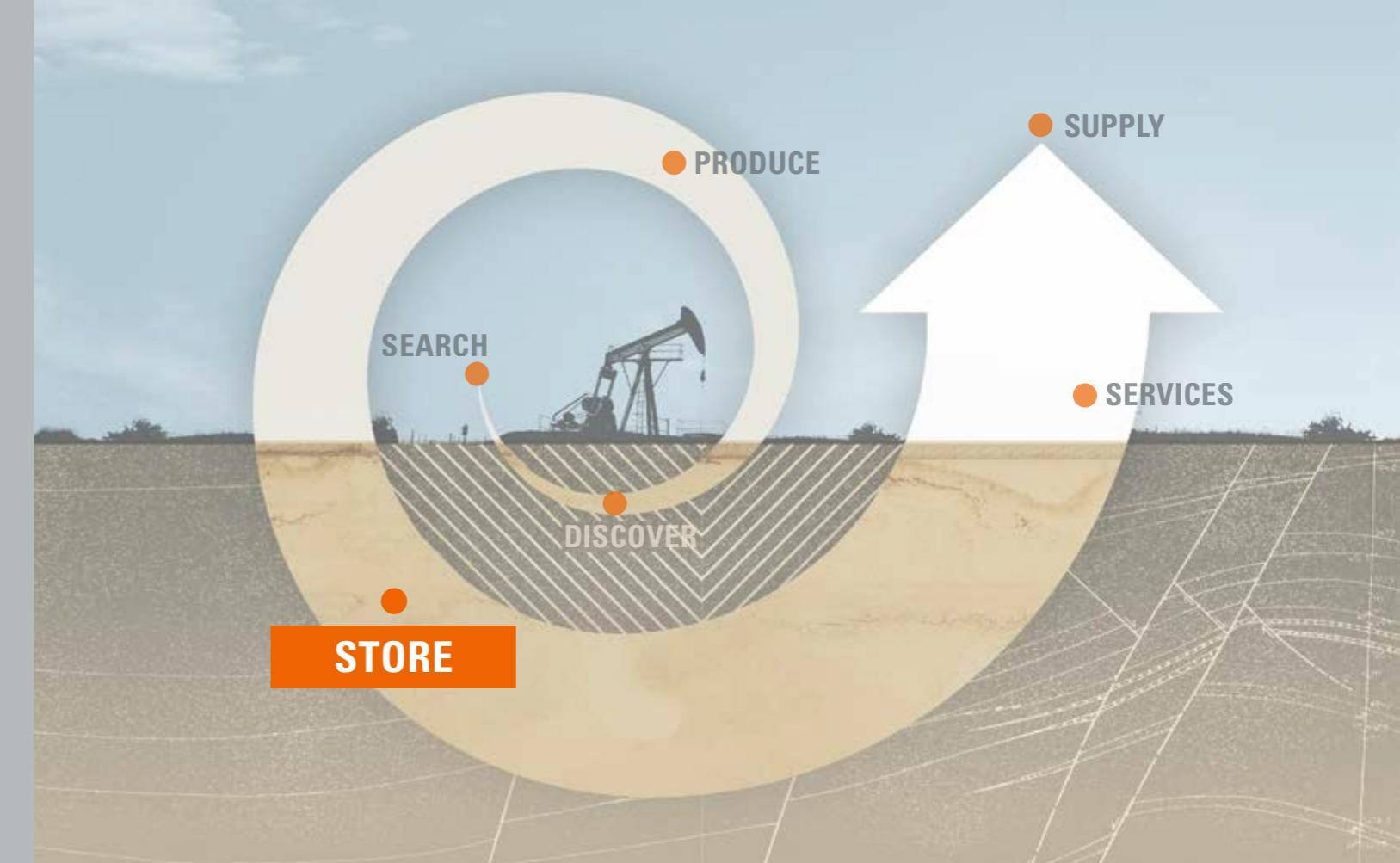
Modern domestic condensing boilers have efficiencies as high as 98 %, and natural gas is also an excellent fuel for power generation. Combined-cycle gas and steam turbine generating stations are among the most efficient conventional power plants. In combined heat and power configurations they deliver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



Company profile

RAG has been making a major contribution to Austria's energy supplies for more than 80 years.

Since its formation in 1935 our company has produced around 16 million metric tonnes of crude oil and 26 billion cubic metres of natural gas at its Austrian fields. Besides carrying out responsible, resource efficient hydrocarbon exploration and production, natural gas storage is a core business for RAG. It recognised the importance of energy storage over 30 years ago, and opened its first gas storage facility, with a capacity of 40 million cubic metres, in Puchkirchen, Upper Austria, back in 1982. Since then RAG has gained a wealth of experience and increased its total storage capacity more than 100-fold, around 6 billion cubic metres; it is now the fourth-largest European storage operator. The company has Europe's most modern storage facilities, and these make a vital

contribution to security of supply in Austria and Central Europe as a whole. Our storage capacity serves both domestic and foreign customers. Oil and gas trading, drilling operations, offering RAG's proprietary E&P solutions and technologies and other services to external clients, as well as projects focused on renewables such as geothermal energy, complete RAG's portfolio of activities. RAG is Austria's oldest established oil and gas exploration and production company. Its extensive experience and technological expertise, highly trained and motivated workforce, and world-class safety and environmental standards make it one of Austria's leading companies.

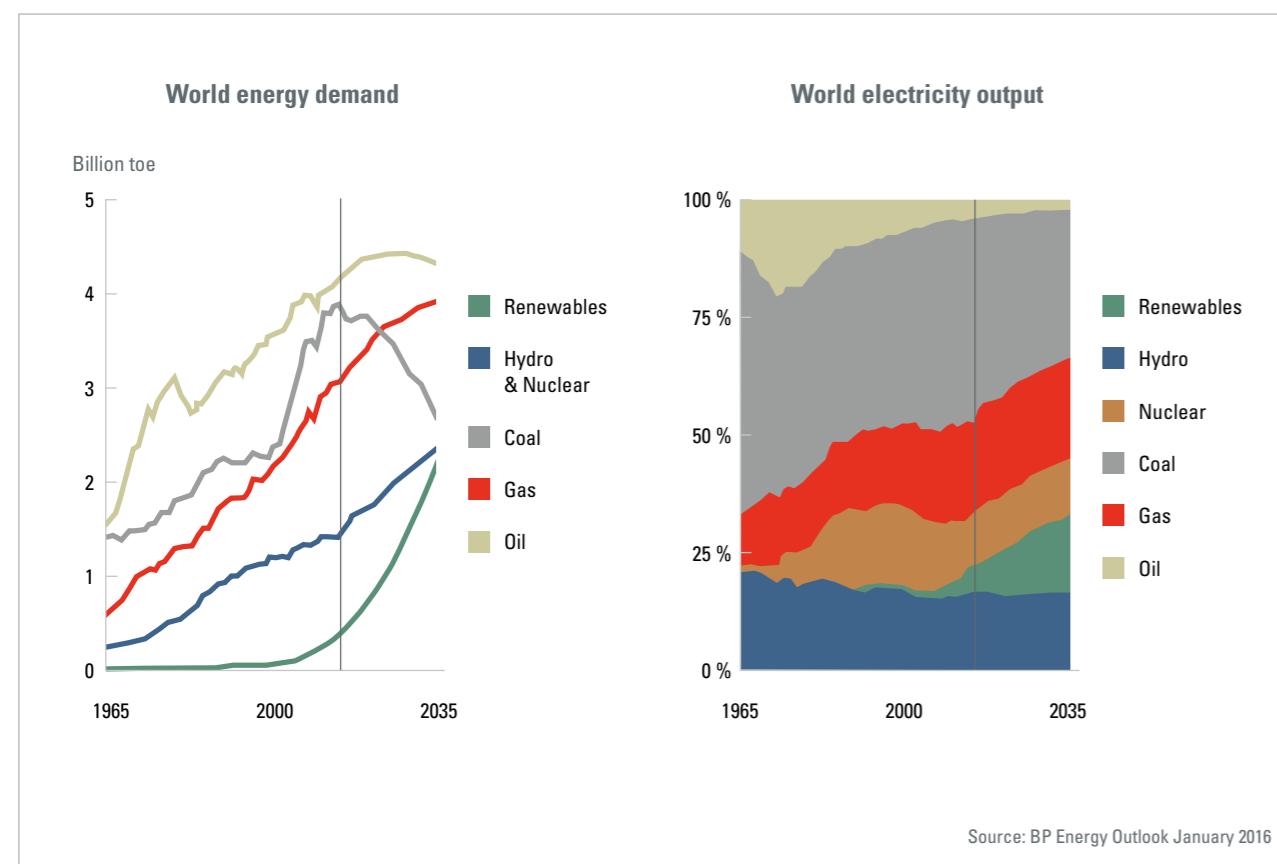
Gas – the energy form of the future

Expert opinion is unanimous that although gas has already become one of the world's main energy sources it still has a long way to go before its full potential is exploited.

Easy to store, climate friendly, and with excellent safety credentials, gas is an indispensable partner to renewables and will provide the secure foundations that tomorrow's energy mix requires. No other energy form has so much to offer in terms of security of supply and innovative potential. This is reflected in the fact that global natural gas demand is steadily rising.

Natural gas is by far the most environmentally friendly conventional energy source. Its suitability for a wide range of household, commercial and industrial uses, and its role in electricity generation are major reasons for its growing importance. It is also extremely energy

efficient, and can be transported underground along existing pipeline networks. Most important of all, gas stands out for its storability. Gas is a key factor in supply security, which is particularly vital to large industrial companies as well as small and medium-sized businesses. But power generation is only half of the story. It will soon be impossible to imagine heating without combined heat and power (CHP) plants, or personal transport without natural gas vehicles. With a range of applications that now rivals oil, natural gas fully deserves its reputation as the energy source of the future.



Power to gas – from wind and solar to fuel



Gas is an ideal and essential back-up for renewables due to its ability to compensate for the large swings in electricity supply and demand.

For their share of the energy mix to keep on growing over the long term, renewables need a means of compensating for fluctuations in output.

Using existing infrastructure

Massive storage capacity is needed for surplus renewable energy to be instantly available during peak periods, and the pumped storage plants used up to now are not large enough to do the job. Power to gas technology is the ideal solution, and a major effort is under way to perfect it. The idea is to convert renewable energy into gas, so as to use existing natural gas infrastructure to transport and store it. The process cracks the biggest problem posed by power storage – the amount of space it takes. Instead of developing new, expensive and technically complex storage methods, gas produced with the aid of solar or wind power (hydrogen or methane) can be transported via the existing pipeline grid and held in storage facilities.

Simplicity itself

The principle behind this new, environmentally friendly technology could hardly be simpler. Surplus solar and wind power is used to split water into oxygen and hydrogen. Up to a point, the hydrogen produced can be directly added to the natural gas stocks. Otherwise it is converted into synthetic methane by a process called methanation, in

which the hydrogen is reacted with carbon dioxide (CO_2). The CO_2 can be drawn from the atmosphere or it can come from a biogas or industrial plant. The product of this process is renewable synthetic natural gas. The process could broadly be described as mimicking photosynthesis. Methane is the main constituent of natural gas, and can make up as much as 98 % of its content. It can be injected into the gas grid, and used in the same way as conventional natural gas – to fuel domestic space or water heating, industrial processes, or fleets of gas vehicles, or alternatively for gas-fired electricity generation. Today the conversion efficiency of the process is already about 60 % – a big step forward in view of the fact that surplus electricity is often not used at all for lack of storage capacity, and whole wind farms taken off the grid.

Underground Sun Storage facility – stocking up on sunshine

Harvesting, storing and supplying solar energy: an unprecedented pilot project run by RAG is currently testing this groundbreaking approach to energy production and storage. Storage of hydrogen, produced using solar energy, is being trialled at a small, depleted gas reservoir.

Thanks to their storability, renewables are the only energy forms that can act as a straight replacement for conventional energy – and Austria's gas storage facilities provide the necessary infrastructure. In terms of the strategic development of energy systems for the future, the results of the pilot will be hugely significant for companies, political decision-makers and public authorities.

The project was selected by an international panel of experts and is being financed by Austria's Climate and Energy Fund.

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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 forth 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

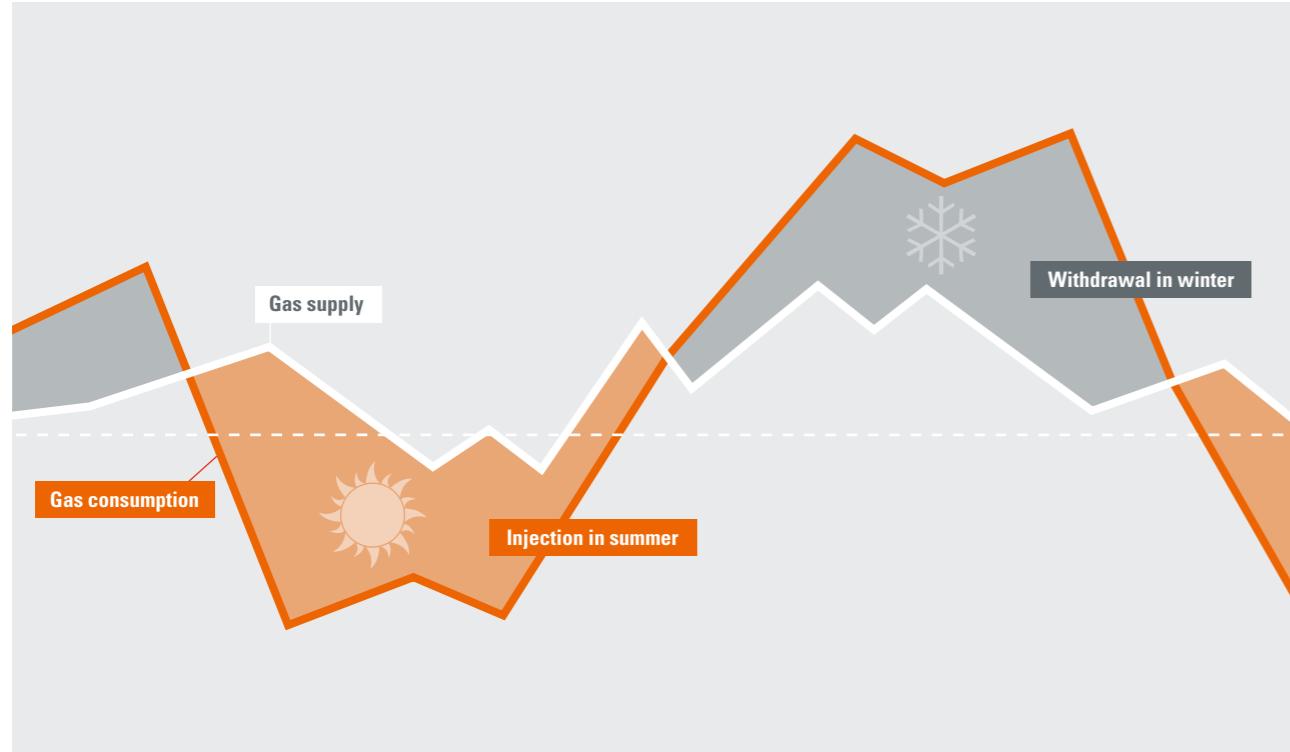
storage capacity, RAG has added a key additional link to its supply chain, and in so doing it has developed a sustainable form of gas production.

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.

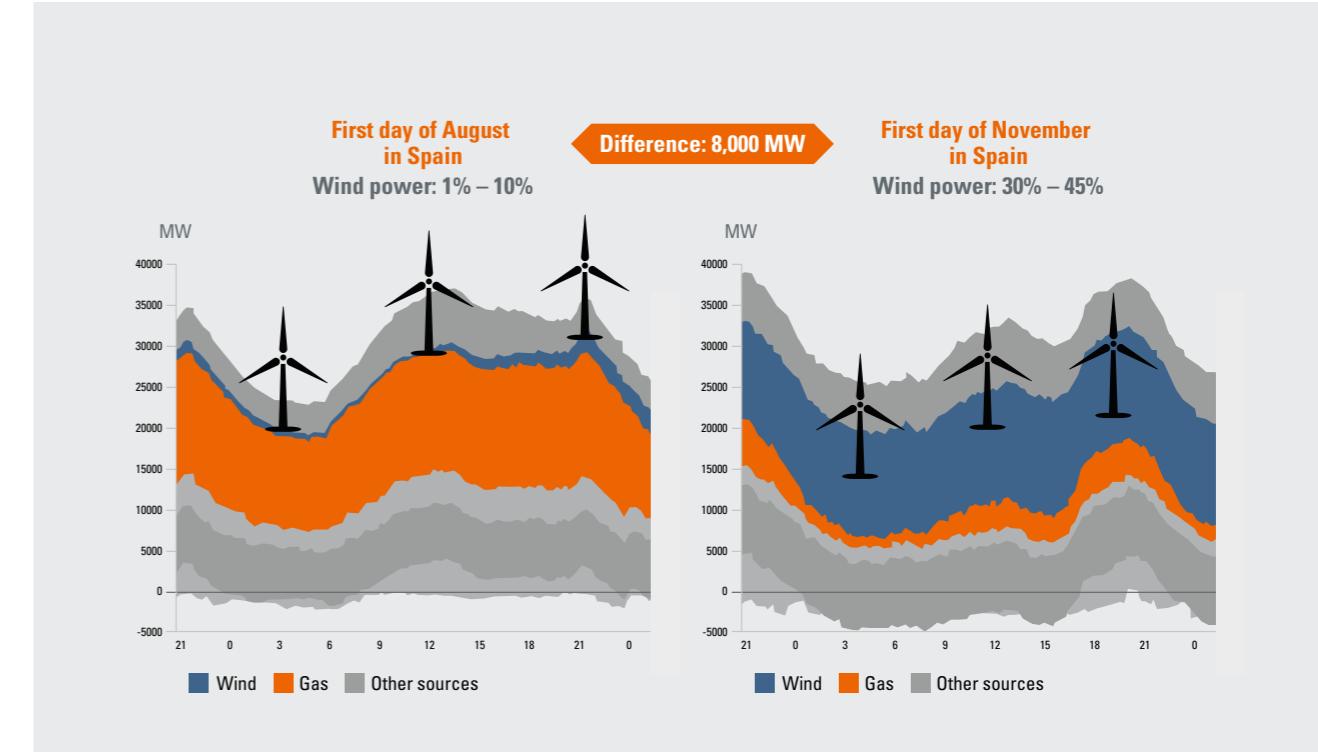


Role of storage facilities

Balancing out seasonal swings



Balancing out daily swings



Compensating for 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 from RAG's storage services?

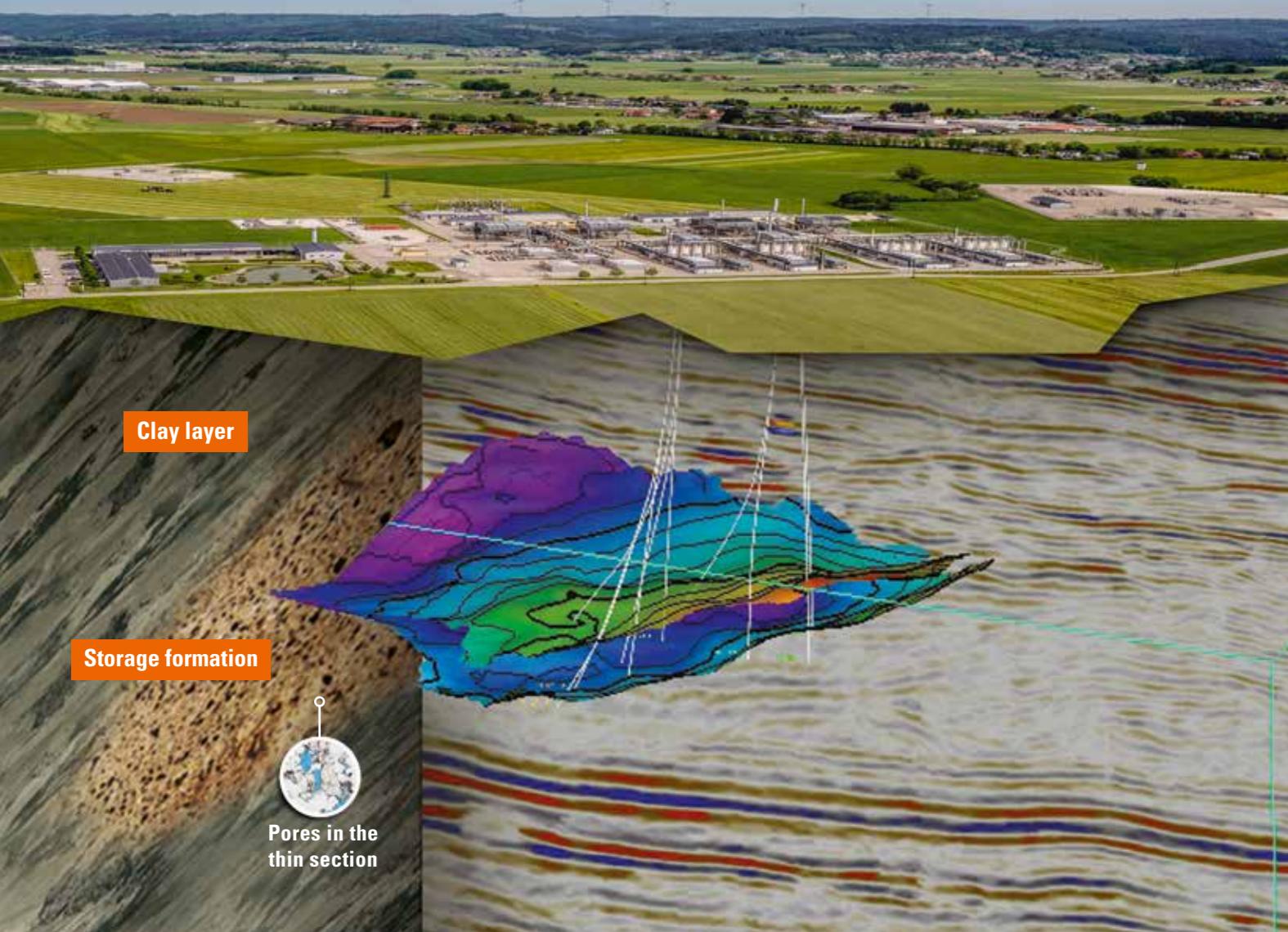
Demand-driven injection and withdrawal of stocks at disused gas fields mean that all users – from industrial consumers to households – can depend on natural gas for safe, reliable and environmentally friendly energy supplies.



Renewables and gas storage – a dream team

Today's growing use of renewable energy sources has given RAG's gas storage facilities a vital new role. 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. For their share of the energy mix to keep on expanding, renewables need a partner to even out these 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 falls in output from wind and solar installations.





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. Modern storage facilities are complex feats 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. Gas can be injected into depleted reservoirs 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. Layers of clay several hundred metres thick overlie the gas reservoirs, and this natural insulating layer makes the underground gas storage extremely safe. 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

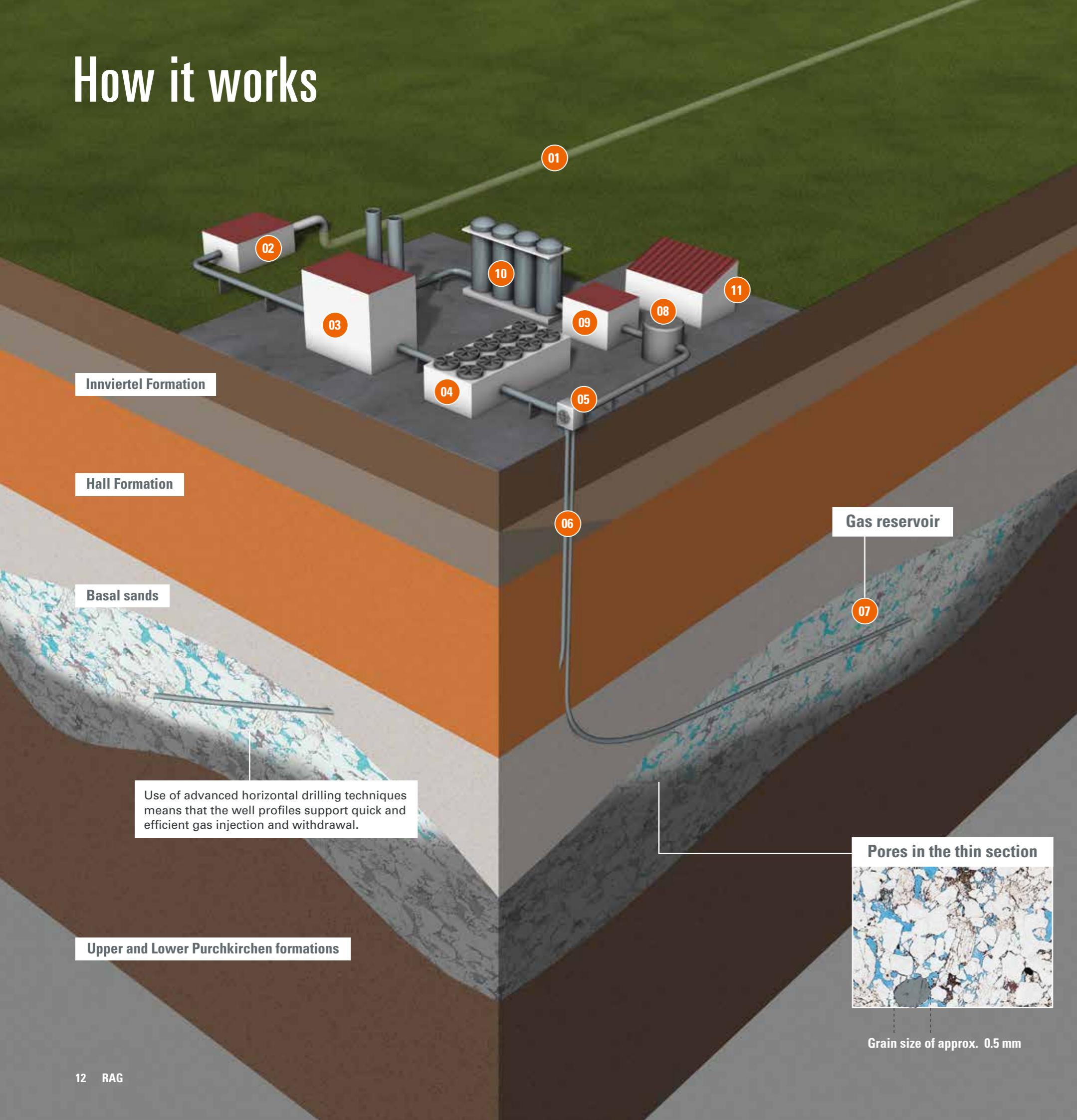


into the reservoirs and withdrawn from them via wells when needed. Surface installations are also required. These include compressors to inject and withdraw the gas under pressure, and equipment to dry and clean it before sending it on its way to consumers. All these process units have been tried and 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.“

*Markus Mitteregger,
RAG Chief Executive Officer*

How it works



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, gas or electric compressors bring the incoming natural gas up to the required pressure. Since compression raises the temperature, the gas must then be cooled before being conveyed to the wellhead and injected into the natural rock formations. The gas is withdrawn when it is needed and processed for transportation. It must be dried and cleaned, as it will have absorbed moisture in the reservoir. Once it is on specification it enters the grid and is carried to the consumer.

Cushion gas

A certain amount of gas is kept in the reservoir as a cushion, enabling the number of wells and the scale of the surface equipment to be kept to a minimum. The working gas above it is injected and withdrawn as required. Optimising the design of storage facilities in this way ensures that operating them is economically viable.



RAG's gas storage facilities

Puchkirchen/Haag gas storage facility

RAG began storing gas 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 expansion of this facility has been carried out in several stages and was completed by 2009. In the summer of that year Puchkirchen was linked with the Haag facility by a 20-kilometre pipeline. The Puchkirchen gas storage facility has a maximum working gas volume of about 1.1 billion cubic metres (= 12.2 terawatt hours), and an injection and withdrawal capacity of 520,000 cubic metres/hour (= 5.9 gigawatts).

2016 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	1,080 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 storage facility

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 130 million cubic metres, and an injection and withdrawal capacity of 50,000 cubic metres per hour (= 566 megawatts).

2016 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	566 MW	50,000 cu m/h
Max. injection capacity	566 MW	50,000 cu m/h

Haidach 5 gas storage facility

The conversion of the former natural gas reservoir into an underground gas storage facility started in 2005. Haidach 5 has a maximum working gas volume of around 16 million cubic metres (= 181 gigawatt hours), and an injection and withdrawal capacity of 20,000 cubic metres per hour (= 226 megawatts).

2016 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 gas storage facility

RAG built this facility as part of the 7Fields project, between 2011 and 2014, and it was commissioned in April 2014. In this facility RAG has a working gas volume of 289 million cubic metres (= 3.3 terawatt hours), an injection capacity of 120,200 cubic metres per hour (= 1.4 gigawatts) and withdrawal capacity of 150,000 cubic metres per hour (= 1.7 gigawatts).

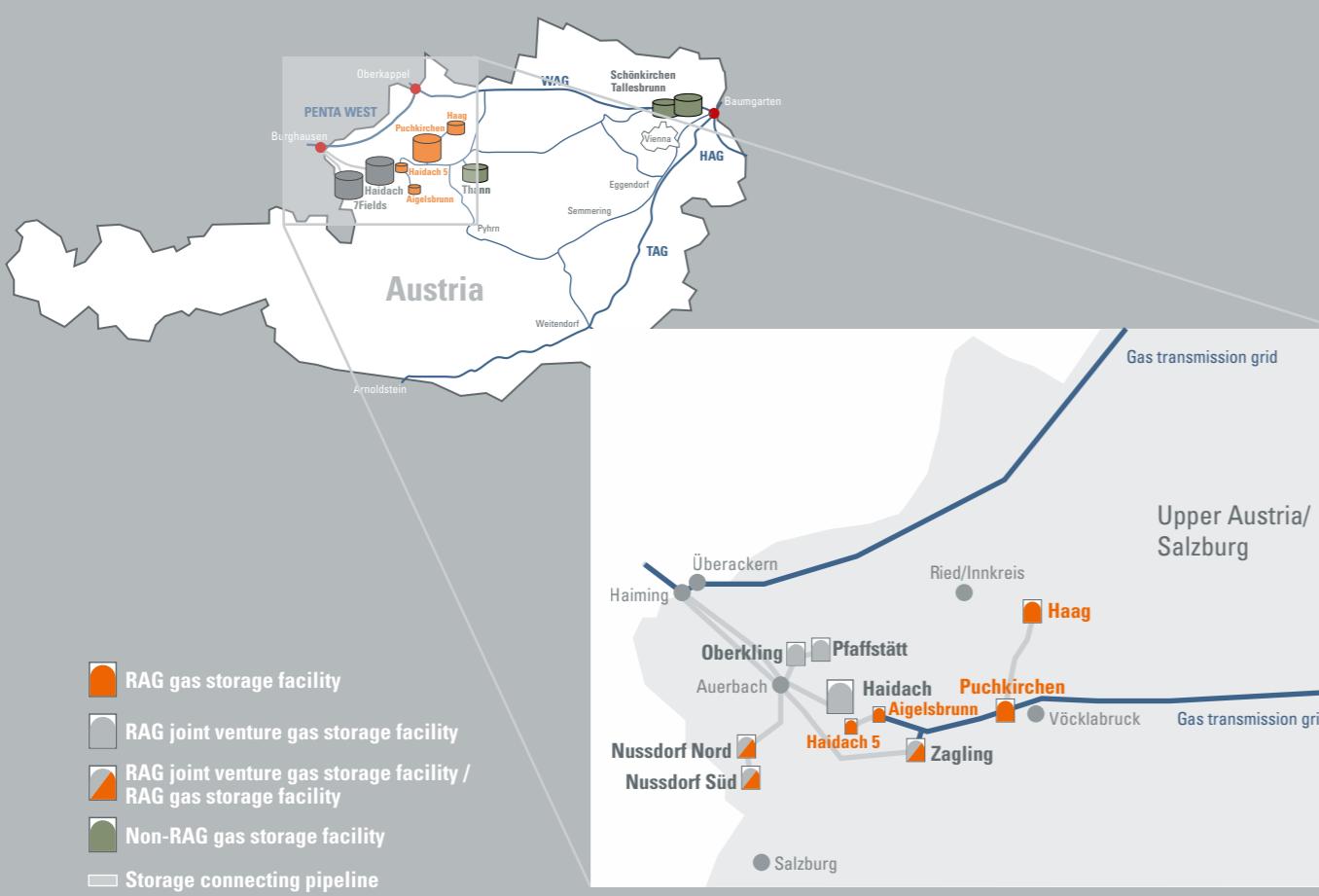
2016 performance indicators (TWh, GW and MW thermal)

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.

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Joint-Venture-gas storage facilities



Haidach gas storage facility

The Haidach gas storage facility is a joint venture project between RAG, its Russian Partner Gazprom Export and Wingas. It was built at an investment cost of about EUR 300 million, excluding cushion gas. RAG was responsible for design and construction and operates the facility. GSA and astora markets the capacity. The first development phase was commissioned in 2007, and the second in April 2011. The total storage capacity of 2.64 billion cubic metres of natural gas is equivalent to a quarter of annual gas consumption in Austria. Haidach is the second-largest storage facility in Central Europe.

2016 performance indicators (TWh, GW and MW thermal)

Reservoir area	3.5 x 5 km
Reservoir depth	1,600 m
Working gas volume	29.9 TWh 2,640 mn cu m
Max. withdrawal capacity	12.4 GW 1.1 mn cu m/h
Max. injection capacity	11.3 GW 1.0 mn cu m/h

7Fields storage facility

The 7Fields facility is a joint venture project between RAG and its German Partner 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 billion cubic metres. 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.

2016 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

Total storage capacity 2016 (TWh, GW and MW thermal)

Working gas volume	66.6 TWh	5,888 mn cu m
Max. withdrawal capacity	31.0 GW	2,743,000 cu m/h
Max. injection capacity	26.2 GW	2,312,200 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.



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