SALT IMPACT STUDY

THE SOCIETAL AND ECONOMIC IMPORTANCE OF SUSTAINABLE SALT MINING IN THE NETHERLANDS

AMSTERDAM, JULI 2022
COMMISSIONED BY NOBIAN

NOBIAN

Roland Berger

Summary

The Dutch government faces a number of important decisions on the future of and conditions for salt mining in the Netherlands. These also include decisions further down the road about granting permits for salt mining. To make these decisions, the government must be able to weigh the benefits against reasonable concerns from local residents, environmental organizations and other stakeholders. Partly to support the government's deliberations and to provide stakeholders with a factual basis, Nobian has asked consultancy firm Roland Berger to conduct an impact study on the importance of salt and salt mining for society and the (sustainable) economy, and on Nobian's role as the largest Dutch salt producer.

Mining salt from its own soil brings the Netherlands (and more broadly Western Europe) security of supply of a crucial raw material for industry and society, and makes it strategically independent of other countries for the production of essential materials for the economy and for the transition to a sustainable world. Salt mining from the Dutch soil is also an economically attractive and sustainable option. There is insufficient capacity to obtain salt from other places in Europe in the short term, and the import of salt from beyond Europe is a less sustainable alternative. In the long term, maintaining salt production in The Netherlands is the most sustainable option for chemical clusters in Northwestern Europe.

In addition, continuing salt mining and chlor-alkali production in the Netherlands will preserve prosperity and jobs in the Netherlands and Western Europe, both at Nobian itself and in the chemical industry that depends on Nobian, and at the suppliers to that industry. Furthermore, salt can be extracted in the Netherlands in a safe and responsible manner, distinguishing it from the extraction of other raw materials such as natural gas.

With Nobian, the Netherlands has a company with highly pertinent expertise and an expressed and demonstrated willingness to take (joint) responsibility for not only its own operations but also the sustainability of Dutch industry and society as a whole. Nobian can also play an important role in the energy transition and in getting the Netherlands "off natural gas". For example, the company has essential competencies that can be leveraged to facilitate hydrogen production and storage capacity.

To ensure that salt mining in the Netherlands can continue in an effective, sustainable and socially acceptable manner in the long term, we have identified a number of conditions for success. For example, the Netherlands can set clear conditions for Nobian with regard to conducting safe, sustainable and responsible operations and maintaining a transparent dialogue about risks and mitigations. The government can also support Nobian's ability to run its core operation effectively and in realizing the acceleration of the company's sustainability agenda.

Considering these success factors, the Netherlands has good and compelling reasons to retain salt mining in the Netherlands for its own and Europe's benefit.

Conditions for success

Public conditions for Nobian

1. Focusing on **safe and responsible operations**, in full transparency about risks and mitigations
2. Maintaining a **proactive and transparent dialogue** with local communities, politicians and government, as well as with all relevant stakeholders and interest groups
3. Investing in **making its own operations more sustainable**, with the primary target of having a 100% carbon-neutral operation by 2040

Required government support for salt production

4. Renewing and continuing to grant **salt mining licenses in the Netherlands**, where the government can set clear conditions for (continued) safe and sustainable operations that Nobian can guarantee, with the standard supervision of SodM
5. Acknowledging the **social importance of salt mining** in and for the Netherlands, as well as distinguishing between the limited aboveground impact of salt mining and the minimal risks of subsidence compared to other forms of mining and extraction

Required government support for Nobian's sustainability agenda

6. Public co-financing – where possible and sensible – of **Nobian's emissions reduction program** to further accelerate emission reduction targets
7. Developing **"fit-for-purpose" legislation and regulation** that make energy transition projects possible and facilitate accelerated permitting processes for new and innovative technologies
8. **Stimulating** the development of a **(green) hydrogen market** in the Netherlands, including the infrastructure needed for it (e.g. for storage and transport)

Contents

1. Foreword

Nobian asked consultancy firm Roland Berger to map out the importance of salt, salt mining and salt-based chemistry for society and the (sustainable) economy, and what Nobian's role is as the largest Dutch salt producer

When we think of salt, we probably think of food. Or of deicing roads in the winter. Some may know that salt is a strategic and crucial raw material for the chemical industry – and ultimately for many of the materials we use and encounter every day. Some may also know that the Netherlands is home to the largest producer of high-purity salt in Western Europe: Nobian (formerly part of Akzo Nobel and once started as the Royal Dutch Salt Industry), a company with over 100 years of experience in salt mining. The Dutch government faces a number of important decisions on the future of and conditions for salt mining in the Netherlands. These also include decisions further down the road about permits. To make a well informed decision, the government must be able to weigh the benefits against – partly due to the experiences with natural gas extraction – reasonable concerns from local residents, environmental organizations and other stakeholders. Partly to support the government's deliberations and to provide stakeholders with a factual basis, Nobian has asked consultancy firm Roland Berger to conduct an impact study on the importance of salt and salt mining for society and the (sustainable) economy, and on Nobian's role as the largest Dutch salt producer.

This report addresses these topics in four parts:

1. **The value of salt and its derivatives** for the chemical industry, for products we encounter every day, and/or for those crucial for a sustainable future;
2. **The process of mining salt from Dutch soil**, in itself and compared to salt extraction through solar evaporation and rock salt mining;
3. **Nobian's role** in the Dutch economy and energy transition; and
4. **The critical success factors** for safe, responsible and sustainable salt mining in the Netherlands.

The first part of the report focuses on the role salt and its derivatives play in the chemical industry and in products we use in our daily lives, and on salt's importance in the production of materials with sustainable applications, such as wind turbine blades, insulation and batteries. The second part of the report explains – from a historical perspective – why salt is mined in the Netherlands and discusses the advantages and disadvantages of the various methods of salt mining. The third part of the report addresses Nobian's operations in terms of sustainability and safety, and discusses the economic, strategic and societal role that Nobian plays in the Netherlands and Europe. The report concludes with the most important success factors for safe, responsible and sustainable salt mining in the Netherlands.

2. The value of salt and its derivatives

Salt and its derivatives are strategic and crucial raw materials for everyday products and products with sustainable applications

Worldwide, more than 320 million tons of salt are produced each year. For reference, that is the weight of about 60 million elephants[A].

Salt is the sixth most produced natural resource (after coal, oil, iron, lignite and bauxite) and salt is distinct in that it is a carbon-free raw material. In Western Europe, we produce about 43 million tons of salt annually (13% of global production). Only a small part of this (about 8%) ends up in our food[B]. Just over a fifth is used as road salt. Most of it is used in industry, agriculture and especially chemistry as industrial salt.

Some of this finds its way as sodium carbonate (soda) to the production of glass, paint, textiles and soap, the desulphurization of iron and, when dissolved in warm water, the disinfection of small wounds; some is processed into sodium chlorate, an oxidizer and herbicide. But most salt (35% of the total and 85% of the salt produced by Nobian) is a raw material for the chlor-alkali process: the electrolysis of a salt solution for the production of chlorine, caustic soda and hydrogen . → A

Through chlorine and caustic soda, salt finds its way into thousands of products that play a major role in our daily lives, such as construction materials, paper, pharmaceuticals, insulation materials, aluminum, soap and more.

Everyone in the Netherlands encounters these products each and every day, no matter what time it is or what they are doing (to illustrate this, see "Chlor-alkali in everyday products"). → B

The fact that salt plays such a large role in our daily lives is because chlorine and caustic soda are base chemicals used in chemistry as raw and/or auxiliary materials for the production of intermediate and final products. Virtually every end market – from construction to agriculture, from energy and electronics to consumer goods, and from automotive

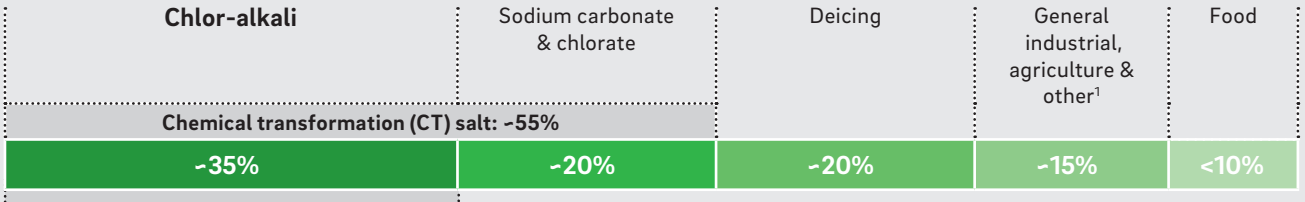
Worldwide, more than 320 million tons of salt are produced each year. For reference, that is the weight of about 60 million elephants

[A] Adult African elephants weigh an average 5.3 tons (between 4.7 and 6 tons). Source: Laursen, L., & Bekoff, M. (1978). Loxodonta africana. Mammalian Species, 92, 1–8. https://doi.org/10.2307/3503889.

[B] Based on salt consumption in Western Europe (2019). Sources: Roland Berger, Nobian.

A Salt and chlor-alkali application areas (Western Europe)

Western European salt consumption, by application



Chlor-alkali applications and end markets (selection)

Chlor-alkali input	Products	Key Applications	Key End Uses
CT salt → Electrolysis	Chlorine	1. PVC 2. PUR 3. Chloromethanes 4. Epoxy	Construction Insulation Consumer goods Packaging
	Caustic soda	1. Organic chemistry [2] 2. Inorganic chemistry [2] 3. Pure caustic 4. Aluminium	Pulp & Paper Soaps/detergents Textile Construction
	Hydrogen	Energy carier	Industry

[1] Other includes water softening & pharmaceutical applications / [2] Caustic soda is a critical input for various processes of a broad range of (in)organic chemicals (e.g. pH-control, dehydrogenation, gas scrubbing) / Source: Nobian, Roland Berger

manufacturing to pharmaceuticals – encounters them. → C

Chlorine plays a role in 40% of organic chemistry [C] and as much as 50% of polymer production. For example, chlorine is used to produce PVC (polyvinyl chloride), with applications such as pipes and profiles in construction, cable insulation and blood bags. Also, chlorine compounds play a role as catalysts of chemical processes and in substitution reactions. One thinks of polyethylene, the most widely used plastic for everything from packaging to cable insulation, children's toys, and bulletproof vests; of PUR and PET bottles; and of polystyrene, which as a hard, solid plastic is used for food packaging, laboratory equipment, automotive parts, and garden planters, and as (styro)foam in insulation materials, industrial packaging for fragile products, and civil engineering.

Over 75% of all pharmaceutical products is

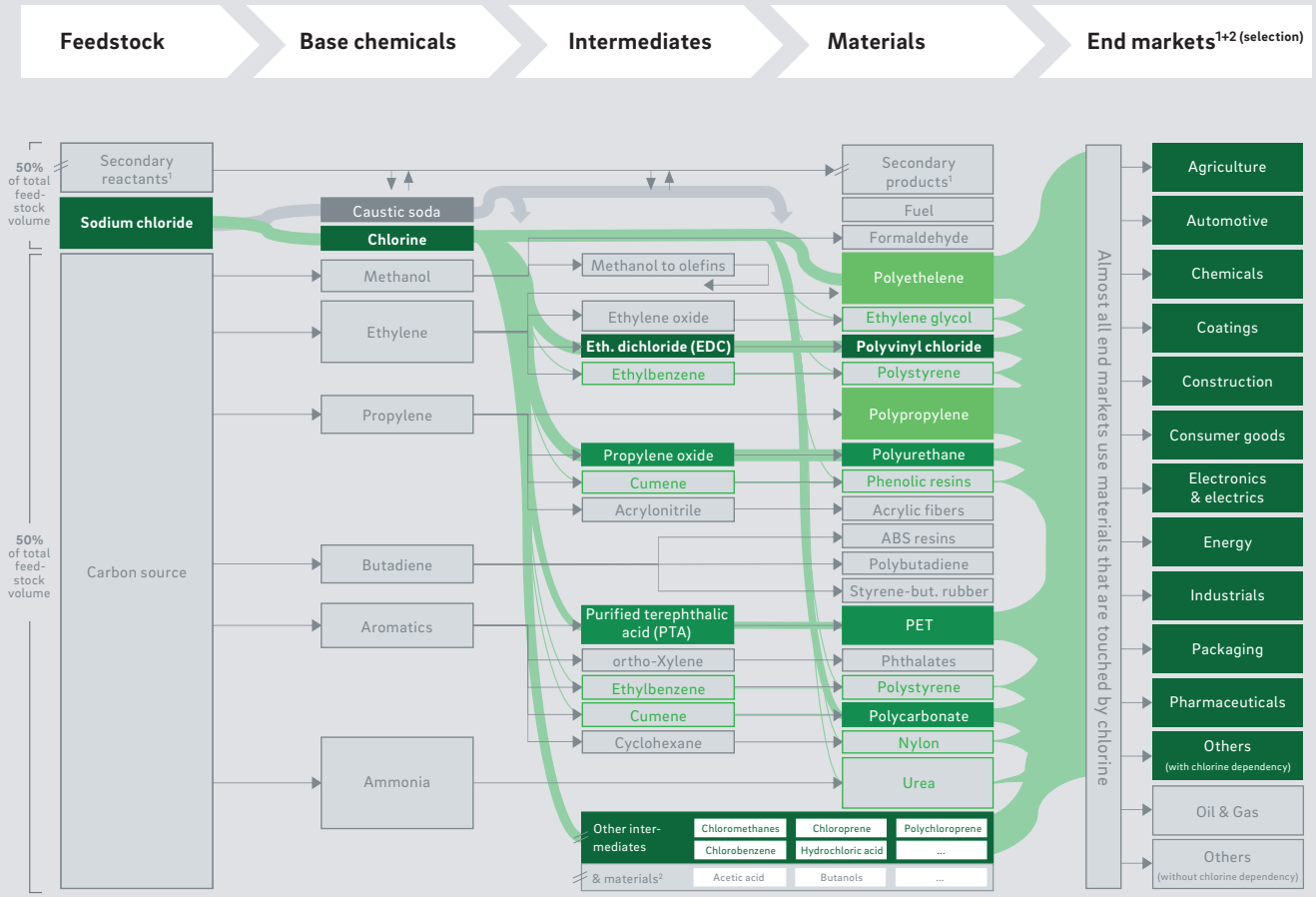
[C] Organic chemistry is defined as the production of carbon-containing intermediate products and materials.

B Chlor-alkali in everyday products (selection)

End market	Product
 **Construction**	• Polyurethane **insulation material** • PVC water and drainage **pipes** • Resistant epoxy and PVC **floors** • PVC **window frames** • Polyurethane **sealants** • **Electronic cables** insulated with PVC • PVC **siding and fences** • **White paint** produced with chlorine
 **Automotive**	• **Car battery** with epoxy binder and caustic reactant • **Aluminum car components**, such as the frame, produced with caustic soda • Polyurethane **seat cushioning and covers** • **Polyurethane and PVC car components,** such as the dashboard panel and the bumper • **Brake fluid and antifreeze,** produced with chlorine
 **Consumer goods**	• **Footwear** with polyurethane soles • Polyurethane **chair cushioning** • Polyurethane **mattress** • **Book** pages, produced with caustic • **Sports (sun)glasses** with polycarbonate lenses • **Vinyl records**
 **Pharmaceuticals & Personal care**	• **Medicines** with chlorine in the atomic structure, or produced with chlorine and caustic soda, in PVC **blister packs** • Chlorine-based **disinfectants** • **Blood bags** made of PVC • **Soap and detergent,** produced with caustic soda • **Deodorant** containing calcium hypochlorite • **Contact lenses** produced with chlorine chemistry

Source: Nobian, World Chlorine Council, Euro Chlor, Roland Berger

C Importance of chlorine in the chemical industry (illustrative)



Share of volume touchedby chlorine (indicative)

Chlorine is involved **in ~40% of organic chemistry volume4[4]**

~50% of polymer product volume is touched by chlorine-based chemistry

Chlorine in structure · Chlorine in precursor · Chlorine as catalyst · Chlorine is used in alternative production method[3]

Indicative volume of chemical · Indicative volume of chorine stream

[1] Not to scale / [2] Colors not according to legend – Green if dependent on chlorine in any way, white/grey if not / [3] Production method that is not the typical/most preferred method / [4] Defined as carbon-containing intermediates and materials / Source: Nobian, Cefic, Euro Chlor, Roland Berger

dependent on chlorine. In 15% of all drugs, chlorine is present in the molecular structure. Chlorine is in nearly half of cancer drugs and even in more than half of the drugs for cardiovascular or nervous system diseases. About 60% of all pharmaceutical products depend directly on chlorine for their production, for example as a precursor or in the form of hydrochloric acid [D].

Caustic soda is used in the production of materials such as aluminum, paper, soap and detergent, and plays an irreplaceable role as a strong base in regulating the pH value (acidity) in chemical processes.

Chlor-alkali production is crucial for not only our everyday products and the industries that make them, but also for the transition to a sustainable world. The house of the future will be built with and on chlor-alkali applications. → D

PVC has many uses in homes, including in durable and recyclable pipes and window frames. PUR is one of the best insulating materials, and its use in insulation in roofs, floors or refrigerators will continue to grow.

Green electricity for light and heat is generated by onshore and offshore wind turbines, whose blades consist of epoxy resin – made with chlorine.

The advanced magnets in the wind turbines are made from rare earth metals that cannot be mined or recycled without the use of chlorine.

Caustic soda is needed to produce energy-saving LED lights in the home and (hybrid) batteries for the electric car in the garage.

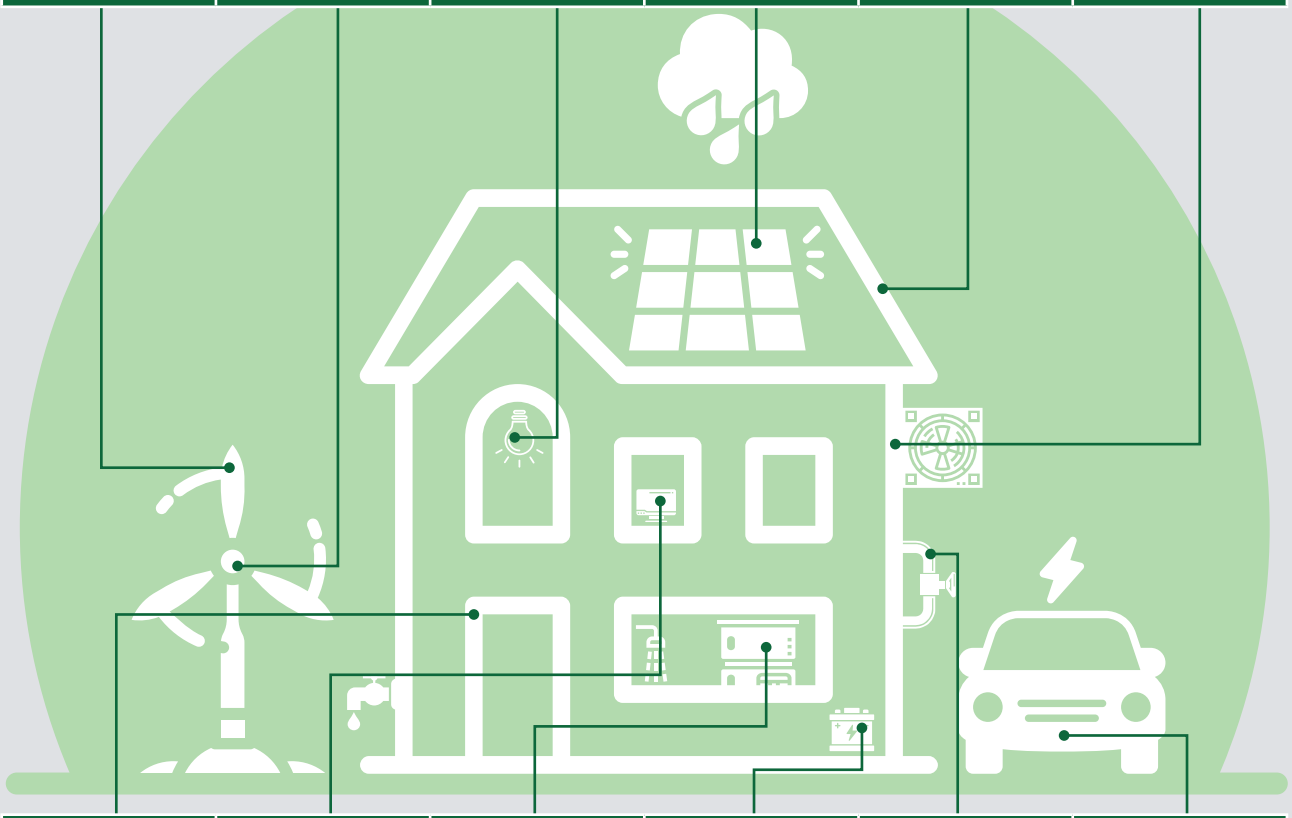
Not to mention the use of salt and its derivatives for the production of optical fibers and chips for computers and smartphones, sustainable coolants for refrigerators, roofing and solar panels.

Over 75% of all pharmaceutical products is dependent on chlorine

[D] An analysis of 1086 FDA-approved small molecule drugs indicates that 15% of these drugs have chlorine directly present in the molecular structure. An analysis of the top-100 bestselling drugs in the United States in 2012 indicates that 60% rely on chlorine for production. Source: Smith et al. Beyond C, H, O, and N! Analysis of the elemental composition of US FDA approved drug architectures: Miniperspective

D Chlor-alkali in sustainable products (selection)

Wind turbine blades	High performance magnets	Energy-saving LED bulbs	Solar cells	Sustainable roofing	Insulating material
Epoxy resin, made using chlorine, is an essential material in windmill blade production to ensure strength and durability; Alternative is polyurethane	Metals in high-performance magnets are extracted from ores through chlorination	Energy efficient LED bulbs are made using caustic soda-treated metals	Silicon is the major component of solar cells and needs purification with HCl	Polyvinyl chloride (PVC) roofing membranes are a sustainable choice due to energy efficiency and higher recyclability	Polyurethane foam, made using chlorine, is a crucial insulating material that maximizes energy efficiency



Sustainable window and door frames	Optic fibers, computer & mobile chips	Sustainable refrigerators	Home batteries	Sustainable piping	(Hybrid) car batteries
Polyvinyl chloride (PVC) frames are a sustainable alternative to wood/ aluminum due to their durability, insulating properties and closed loop recycling potential	Chloride precursors are required to produce optic fibers, and computer & mobile chips require silicon purified with hydrogen chloride	Chlorine is used to produce polyurethane insulation material and the most sustainable refrigerants	Lithium-ion batteries, which use chlorine in the production process, are efficient for storing renewable energy	The longer lifespan and multi-cycle recyclability of polyvinyl chloride (PVC) pipes makes them sustainable to metal/steel/ concrete alternatives	Epoxy is a key binder and caustic soda is a key reactant in synthesis of battery materials

Source: Nobian, Euro Chlor, World Chlorine Council, Roland Berger

3. The salt-mining process

The Netherlands is in the singular position of having large and easily accessible salt reserves. Salt mined from Dutch soil is pure, which is suitable for chemical applications, and its extraction can be done safely, responsibly and sustainably (subject to certain conditions)

There are three ways to mine salt, namely solar evaporation, rock salt mining and solution mining. Solution mining produces salt of high purity, but requires a relatively large amount of energy

The value of salt has been recognized since ancient times. It was mined as early as the Copper Age – near Solnitsata (literally "salt spring"), the oldest city in Europe according to Bulgarian archaeologists, which flourished between 4,700 and 4,000 BC – and in the Bronze Age, such as near Salzburg (also named after salt). About 3000 years ago, the Chinese were the first to use artificial salt pans, and the Romans also laid out salt pans across its empire. Later, the Romans even paid their legionnaires in salt rather than money, which is where we get the word "salary" (from the Latin word for "salt," although the exact link is lost).

Today, there are three ways to mine salt:

I. In **solar evaporation**, artificial basins (salt pans) are laid out to collect seawater or water from other naturally occurring saltwater sources. Sun and wind evaporate the brine, leaving salt behind in crystal form [E]. The principle has not changed for centuries. Important conditions are a hot, dry and windy climate and the availability of sufficient (flat) space for the salt evaporation ponds and salt pans. In Europe, this type of mining mainly takes place in the Mediterranean region: in Spain, Italy, France and Greece. This method accounts for 9% of the salt production in Western Europe.
II. In **rock salt mining**, salt is extracted from salt-containing rock strata using excavators and other machinery, sometimes in combination with explosives. These salt layers are the result of prehistoric oceans that dried up, often hundred millions of years ago, and were covered over time by layers of rock; they are often deep underground. In Europe, rock salt mining mainly takes place in Germany and the United Kingdom. This type of mining accounts for 37% of the salt production in Western Europe.
III. In **solution mining**, holes are drilled in the underground salt layer and two pipes are inserted. Water is injected into one of these pipes to dissolve the salt, and the other pumps up the saltwater (brine) for further processing into either purified brine or dry salt (vacuum salt). As with rock salt mining, the presence of an (accessible) underground salt layer is a requirement for this type of salt mining. Accessibility depends on the depth of the salt layer or the presence of "salt pillars" (salt domes): pillar-shaped structures that come relatively close to the Earth's surface, created when rock salt has been pushed upwards. Dissolving and pumping salt out from these pillars creates cavities or "caverns." When these caverns are the right shape and size, and once a permit is secured, they can serve other purposes, such as storage for hydrogen or compressed air. Solution

[E] Water can also be evaporated in ways that are not naturally occurring, such as by using steam or mechanical vacuum recompression (MVR).

mining takes place in countries such as the Netherlands, Germany, Spain, France and Austria. About 54% of the total volume of salt in Western Europe is produced through solution mining.

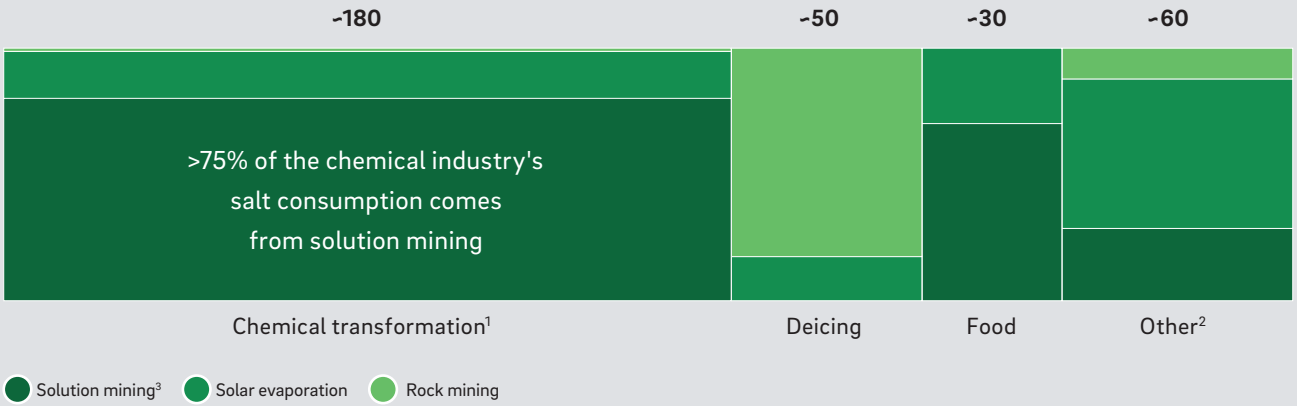
The advantage of solution mining is that after processing it produces a high-purity salt that is very suitable for the chemical industry. As a result, this type of salt accounts for more than 75% of global chlor-alkali and soda production. Salt from rock salt mining or evaporation must undergo additional purification steps before it is suitable for use in the chemical industry. Rock salt is therefore mainly used as road salt, where purity is less important. → E

A second advantage of solution mining is that it requires relatively little land. In this type of salt mining, a well is drilled and, once the mine is in operation, visual pollution is limited to the "well pad" (and in Twente to the "salt house") under which the well is located. This distinguishes it from the evaporation method and rock salt mining, which require (much) more land.

One disadvantage of solution mining is that a relatively large amount of energy is required to dry or vacuum dry the salt. Thus, energy consumption for the production of high-purity salt from solution mining is higher than for salt produced from rock salt mining and solar evaporation.

It should be mentioned, however, that solution mining is at the forefront of sustainability efforts, with concrete implementation steps and plans in the industry to mitigate this energy disadvantage. To make a fair comparison, it is also important to look at the entire emissions picture of salt in practice, including, for example, transport and any additional purification steps required (to make it suitable, for example, for use in the chemical industry). For this reason, Nobian requested a life cycle assessment (LCA) from the technical consulting firm Ecomatters, where the emissions of alternative salt sources were compared with its own salt production (see later in this chapter).

E Global salt consumption per salt type and application ['000 kt] (illustrative)



[1] Sodium chlorate is also a chemical transformation outlet for salt, but is captured under "other" / [2] Includes e.g. feed, pharma, water softening, industrial / [3] Assumed brine salt to be mined through solution mining / Source: Nobian, Expert interviews, Roland Berger

F Overview of advantages and disadvantages by salt production method

	Solar evaporation	Rock salt mining	Solution mining
Salt source	Naturally occurring saltwater springs	Underground salt deposits	Underground salt deposits
Productionprocess	Evaporation	Mining	Injection of water & pumping out of brine Purification Crystallization & Centrifuging
Salt type	Solar salt[1]	Rock salt	Brine (purified) Vacuum salt
Share of salt production (Western EU)			
Top 3 producers (Western EU)			
Main applications	Food, Chemical industry[2], Deicing	Deicing	Chemical industry[2], Food
Purity	Medium	Low	High
Salt production per required aboveground[3] surface area	Low	Medium-High	High
Energy efficiency	High[4]	Medium-High	Low
Degree of suitability as an input for the chemical industry in North-West Europe	 → Limited capacity available in Europe → Transport of solar salt from the Mediterranean to North-West Europe has negative impact on costs and emissions → Additional purification steps required for use in chemistry	 → Low purity of salt - Multiple purification steps needed to reach the required purity level, with negative impact on energy use and costs → Worldwide, rock salt is not/ barely used as an input for chemical industry	 → High purity level makes solution-mined salt suitable to use as input for chemistry → Solution mining takes place near chemical clusters (Netherlands and Ruhr region), resulting in little transport (and few additional costs and emissions)

Low High

[1] In addition to solar salt, vacuum salt can also be produced based on evaporation when additional purification steps are added to the process / [2] Also called Chemical Transformation / [3] For rock salt mining in Europe, most mining activities are executed below ground – Only aboveground mining buildings and equipment are considered / [4] Energy consumption is low in the case of solar evaporation. When non-natural drying methods are used, the energy consumption is high

Source: Expert interviews, Research papers, Roland Berger

Figure F summarizes the advantages and disadvantages of each salt mining method mentioned above. → F

Salt mining from Dutch soil produces salt suitable for Dutch industry and is the most sustainable option for chemical clusters in Northwestern Europe in the short and long term

The Netherlands is in the singular position of having large salt reserves that are easily accessible and can be mined safely and responsibly through solution mining. The Zechstein Sea dried up 260 million years ago into an underground salt layer that extends under the Netherlands, Germany and Poland. In the Netherlands, the Zechstein layer is easily accessible for salt mining in a number of places. In Twente, for example, the salt layer lies relatively close to the Earth's surface (at a depth of less than 1 km). In the northeastern part of the Netherlands, the salt layer lies deeper (between 1 and 5 km depth) but there are salt pillars in 14 places where the salt has been pushed upwards close to the Earth's surface, including in Heiligerlee, Zuidwending and Zuiderveen [F]. → G

About 6 million tons of salt are extracted each year in the Netherlands – by far the most by Nobian (about 5 million tons), which has a concession for salt mining in several locations in the Netherlands. In all of these concessions areas, Nobian produces salt through solution mining of such high purity that it is almost entirely used in the chemical industry in the Netherlands and its surrounding areas. There are no sufficient alternatives in other places in Europe to replace the amount of salt from the Netherlands: salt produced from evaporation ("solar salt") or rock salt mining must undergo additional purification steps to be used in the chemical industry and, especially in the case of solar salt, must come from relatively far away. There is also insufficient capacity to acquire salt from other parts of Europe in the short term.

Importing salt from outside Europe means even more emissions, and encounters capacity and logistical constraints. A life cycle assessment (LCA) comparing the import of rock salt from Chile and solar salt from Mexico with Dutch salt shows that these alternatives entail double the amount of CO_2 emissions compared to Dutch production, mainly due to transport [G].

In short, there are no good short-term alternatives to replace the salt that Nobian produces. Even in the long term, retaining salt mining domestically – also in view of the planned emissions reduction program – is the most sustainable option for chemical clusters in Northwestern Europe.

Salt mining from Dutch soil can be done safely, responsibly and sustainably (subject to certain conditions)

The safety of salt mining is an important theme for the Netherlands and for Nobian. Salt mining from Dutch soil has been taking place for more than a hundred years and can, under certain conditions, be carried out safely and responsibly. Unlike peat cutting, for example, solution mining does not damage the landscape. Unlike the extraction of natural gas, the extraction of salt from the soil rarely leads to seismic activity.

Yet salt extraction is not entirely risk-free. For example, oil sealant from old wells in Twente (drilled in the 1980s) leaked into the surface- or groundwater [H].

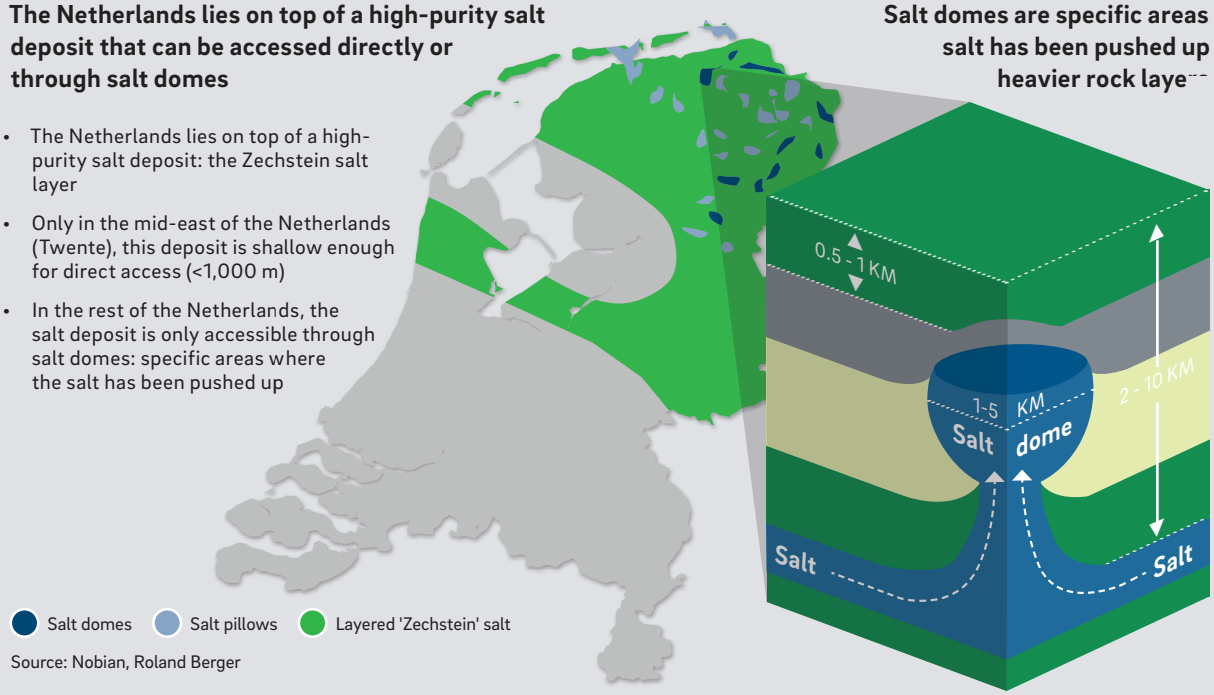
[F] In the Netherlands, the majority of the underground salt layer is between 1 km and 5 km deep.
[G] Based on a life cycle assessment (LCA) conducted by technical consultancy firm Ecomatters at the request of Nobian (2022).
[H] Source: State Supervision of Mines (https://www.sodm.nl/sectoren/zoutwinning/veelgestelde-vragen-over-zoutwinning).

G Availability of accessible salt in the Netherlands (illustrative)

The Netherlands lies on top of a high-purity salt deposit that can be accessed directly or through salt domes

- The Netherlands lies on top of a high-purity salt deposit: the Zechstein salt layer
- Only in the mid-east of the Netherlands (Twente), this deposit is shallow enough for direct access (<1,000 m)
- In the rest of the Netherlands, the salt deposit is only accessible through salt domes: specific areas where the salt has been pushed up

Salt domes are specific areas where salt has been pushed up by the heavier rock laye-- on top



Source: Nobian, Roland Berger

This was the reason for the State Supervision of Mines (SodM) to place Nobian under enhanced supervision. Nobian subsequently set up maintenance management systems for wells and pipelines. In almost all case files, enhanced supervision has now been reduced. At this time, enhanced supervision still applies to two case files, namely the closure of large caverns in Groningen and the stabilization of a small number of potentially unstable caverns in Twente.

Another risk of solution mining is soil subsidence. Subsidence can occur, but it is minimal, gradual and predictable. Soil subsidence is very limited and can be minimized by, for example, adjustments in water management. The Ministry of Economic Affairs states that to date, no perceptible and/or damaging vibrations have occurred in the Netherlands as a result of salt mining, and that the chance of damage to buildings as a direct result of subsidence is negligible[I].

Nowadays, caverns are continuously monitored using sonar techniques, which means that potential subsidence can be anticipated 10 to 15 years in advance and measures can be taken. With the vigilance of and precautionary measures taken by responsible companies and the State Supervision of Mines, the risks are, according to experts, minimal and can be well mitigated and monitored.

[I] Source: Dutch Ministry of Economic Affairs (https://mijnbouwvergunningen.nl/cms/view/9b149871-75f8-4677-9f56-0389bed0f771/over-mijnbouw/c9ad7b1c-28d2-466c-8074-862ab93dfd1d).

4. Nobian's role

Nobian is a leading European player in salt and chlor-alkali products that are economically and strategically important to Europe, is pursuing an ambitious green agenda and is playing a key role in the energy transition

With Nobian, the Netherlands has a company with the history, expertise and sense of social responsibility for safe, responsible and sustainable salt mining

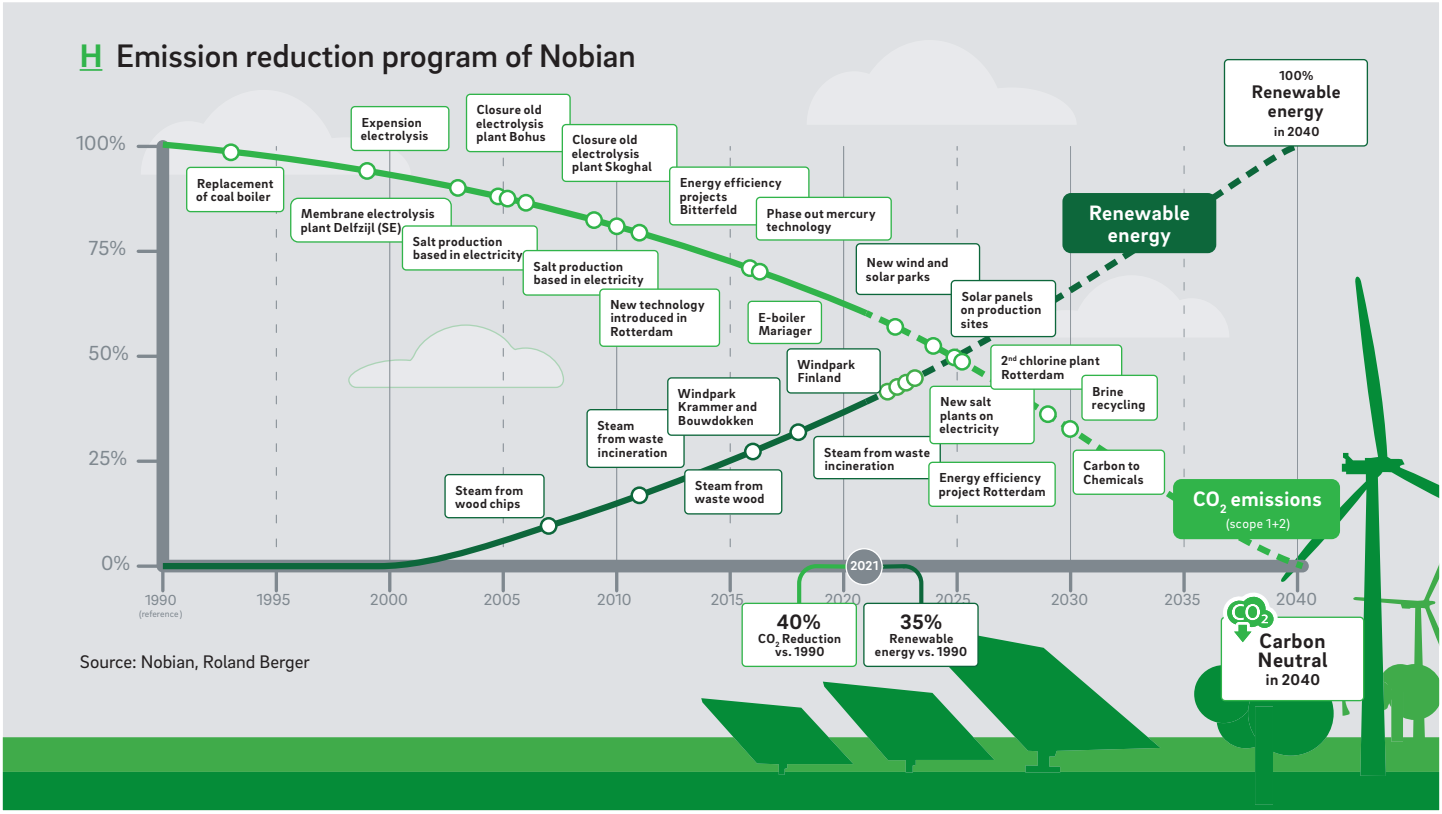
Nobian has more than a century of experience in salt mining from Dutch soil. At this moment, Nobian produces salt in two locations in The Netherlands an in one location in Denmark. Additionally, Nobian operates chlor-akali plants in five locations in The Netherlands and Germany.

Nobian is committed to structuring and continuing its operations in a responsible, safe and sustainable manner. In this regard, Nobian is taking the lead in areas such as sustainability and is working hard to implement safety improvements. For example, the number of safety incidents has been reduced to below the chemical industry average [J], and in the periods 2010-2022 and 1990-2022, Nobian cut its CO_2 emissions by respectively 30% and 40% [K].

In addition, Nobian has set up an ambitious emission reduction program, with the main target having 100% carbon-neutral operations by 2040. → H

Further acceleration of Nobian's sustainability program is possible with government support in terms of permits and financing of otherwise unprofitable investments.

H Emission reduction program of Nobian



Source: Nobian, Roland Berger

Nobian has set up an ambitious emission reduction program, with the main target having 100% carbon-neutral operations by 2040

A benchmark study among European competitors reveals Nobian as an industry leader in this regard[L].

The majority of its competitors, for example, either do not have a concrete target for carbon-neutral operations or only want to achieve this target by 2050.

Nobian is also among the frontrunners when it comes to using renewable (green) energy. For example, Nobian is part of the VEMW Wind Consortium for Hollandse Kust West and is working hard to electrify its processes to move away from natural gas.

Nobian's goal is to fully replace the energy it uses in its processes – equal to the annual energy consumption of 733 thousand individuals in the Netherlands and to approximately 0.9% of Dutch natural gas consumption – with renewable energy.

The company is also committed to flexible production. For example, production at the chlor-alkali plant in Rotterdam can be adjusted on a minute-by-minute basis to respond to demands on the national power grid. In this way, Nobian contributes to absorbing peaks and throughs in national power production.

In addition, Nobian is working with its customers to make the production processes of PVC, epoxy and PUR, for example, more sustainable and to maximize the reuse of chlorine (or salt).

[J] The number of reported incidents per 100 employees (200,000 hours) decreased from 2 to 0.5 in the period 2018 to 2021.
[K] Scope 1 and scope 2 CO_2 emissions.
[L] Based on a "Sustainability Peer Assessment" conducted by Accenture at the request of Nobian (2021).

The history of Nobian

1887

A farmer in Twente sinks a well for drinking water. He strikes brine at a depth of 250 meters.

1918

Drilling for salt starts at a depth of 325 meters.

1926

The first vacuum salt plant. Even today, a 'salt mine' is still no more than a small house in a field.

1931

Chemical production plant starts operation.

1936

First salt produced in Hengelo.

1958

Start of salt electrolysis in Delfzijl as one of the first companies of its chemical cluster.

1961

Chlor-alkali plant in Rotterdam. Chemical park Botlek is born.

1964

Annual output of salt exceeds 1 million tons for the first time.

1970

Formation of Akzo, the 4th biggest company in the Netherlands and the 10th biggest chemical company in the world.

1994

Akzo merges with Swedish company Nobel Industries to form AkzoNobel.

2018

100 years of salt production in Hengelo. AkzoNobel splits into Nouryon producing chemicals and AkzoNobel producing paints and coatings.

2021 ◆ NOBIAN

Nobian, which operated as a division of Nouryon when AkzoNobel's chemical business was split off, is launched as an independent company

Source: Nobian, Roland Berger

The company's oldest predecessor, Koninklijke Nederlandse Zoutindustrie (KNZ), was founded in 1918 and started mining salt in Boekelo the following year, and later in Hengelo.

It was an innovative company from the start. As early as 1926, for example, it produced salt using a new method where the brine was no longer boiled down but vacuum dried.

In 1931, KNZ expanded with the construction of a chemical plant for the production of chlorine, caustic soda and more.

Mergers with Ketjen, Koninklijke Zwanenberg Organon and the Algemene Kunstzijde Unie in the 1960s created one of the first Dutch multinationals, with more than 100,000 employees and activities in chemicals, pharmaceuticals, paints and synthetic fibers.

This AKZO – which became Akzo Nobel after the takeover of Nobel Industries in 1994 – was partly responsible for the chemical clusters in Botlek and Delfzijl in the second part of the 20th century.

In 2018, Akzo Nobel's chemical branch was sold to The Carlyle Group and Singapore's GIC, and then continued under the name Nouryon.

In 2021, Nouryon split off the Industrial Chemicals division as the standalone company Nobian.

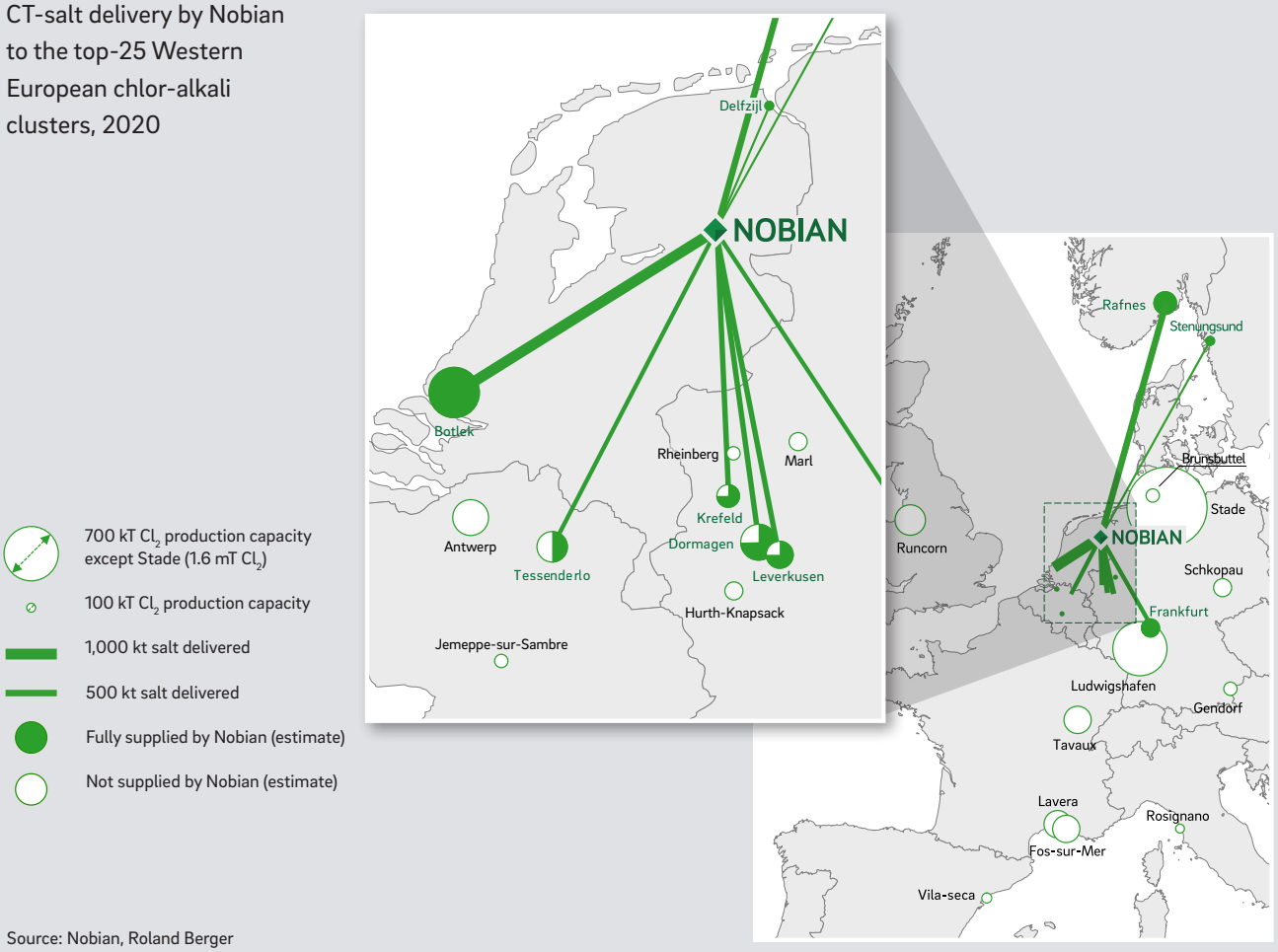
Nobian is economically and strategically important to the Netherlands and Europe

Today, Nobian is the second largest producer of salt in Western Europe (with ~12% of the total) and the largest when it comes to high-purity salt (i.e. solution-mined salt). Nobian employs more than 1,500 people and its sales exceed EUR 1.5 billion. The company supplies almost a third of chlor-alkali demand in Western Europe. Nine of the top 25 chlor-alkali clusters in Western Europe rely heavily on Nobian for the supply of salt. → I

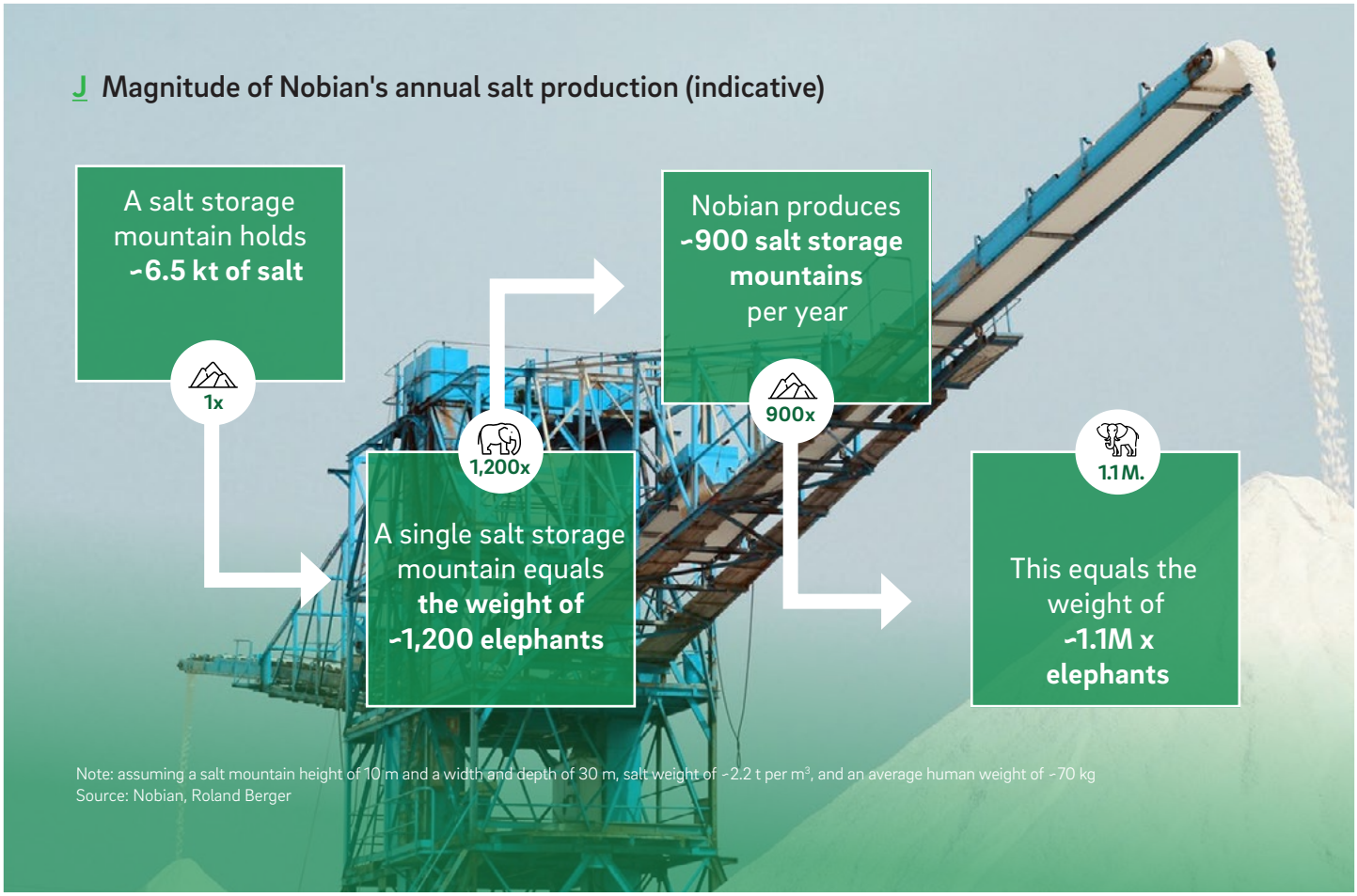
In the Netherlands, for example, Nobian is at the heart of important chemical clusters such as the Botlek and Chemie Park Delfzijl. In the Botlek, for example, Nobian supplies chlorine by pipeline to Shin Etsu, Huntsman and Westlake for the production of PVC, MDI (for PUR) and allyl chloride (for epoxy), respectively. In total, more than 10,000 employees in

I Top-25 Western European chlor-alkali clusters that depend on Nobian's salt

CT-salt delivery by Nobian to the top-25 Western European chlor-alkali clusters, 2020



Source: Nobian, Roland Berger



the Dutch chemical industry depend (in)directly on Nobian. Also in other Northwestern European countries Nobian is an important supplier of salt for chemical clusters. → J

As such, Nobian plays a pertinent role in securing strategic independence and autonomy in the Netherlands and Europe in the areas of salt and essential materials for construction and sustainable applications, such as PVC, PUR and epoxy.

The European trade in salt entails mainly internal supply, about half of which comes from Dutch and German producers. Europe imports only about 2% of its salt, primarily from Tunisia and Egypt and for use as road salt. This differs from countries such as the United States and China, which do partly depend on other regions to meet their salt demand. The relatively high cost of transporting salt as a low-priced "commodity" product also means that imports from other regions have a negative impact on the competitiveness of the user. In this regard, nearby production usually means an advantage in terms of costs – in economic terms, as well as in emissions.

Salt is one of the natural resources available in the Netherlands – in addition to natural gas, petroleum, peat, sand and gravel, and a last bit of marl – that make the Netherlands and Dutch industry self-sufficient and independent of imports from other, possibly less stable, countries.

Nobian is an important partner for the Netherlands in making society and industry greener

Nobian can play an important role in making the chemical industry more sustainable and in accelerating the energy transition. However, Nobian's ambition goes beyond just making its own operations more sustainable. In its vision "Grow Greener Together", Nobian announced its intention to take an active role in making Dutch society greener and more sustainable.

Indirectly – as a producer of ingredients essential to the energy transition and production of sustainable solutions – Nobian is already an important part of the puzzle that must lead to sustainability.

Directly, as a knowledge partner and technology supplier, Nobian also wants to make an important contribution to the industry. Here, the company can draw on more than 100 years of experience in chemical processes and the expertise to develop and implement alternatives that are sustainable as well as technically and economically feasible.

As a knowledge partner, Nobian contributes its expertise, for example:

- As a partner in the "Carbon2Chem®" consortium, which aims to **reduce emissions in the steel industry** by capturing CO_2 and using new technologies to convert it into methanol; this methanol can then be used again as a feedstock for the chemical industry, realizing a circular carbon chain as a result
- As an initiator of a partnership that is developing a **sustainable alternative to cement production** – one of the most carbon-intensive industries, responsible for about 8% of all CO_2 emissions worldwide [M] – based on residual waste from the incinerator
- In the collaboration with Vulcan Energy for the conversion of lithium chloride to lithium hydroxide through electrolysis, as part of Vulcan's ambition to supply "**Zero Carbon Lithium™**" for batteries in electric vehicles (among others) [N]; Vulcan hopes to be able to meet a large share of European lithium needs in the future, thus not only helping to enable the transition to a sustainable world but also reducing European dependence on other geopolitical regions – Australia, South America and China – for this crucial raw material.

In addition to these examples, Nobian is part of "The Institute for Sustainable Process Technology", which aims to drive sustainable innovation and circularity in the process industry, and of "GroenvermogenNL", a consortium that aims to scale up the production and use of green hydrogen in the Netherlands and, to this end, is realizing hydrogen pilots, research projects and educational programs throughout the country with the support of the National Growth Fund ("Nationaal Groeifonds"). In the chemical clusters that Nobian supplies, it plays an important role in making production processes more sustainable and circular, for example in the area of reusing salt and hydrochloric acid.

[M] According to the Chatham House think tank.
[N] Source: https://v-er.eu/zero-carbon-lithium/.

Nobian has essential competencies for the energy transition and for realizing the hydrogen ambition of the Netherlands

Nobian can play an important role in the energy transition and getting the Netherlands "off natural gas". The Climate Agreement ("Klimaat Akkoord") sees the transition to green hydrogen as one of the most important ways to achieve the Dutch targets for CO_2 emissions reduction [O]. In the medium to long term, (green) hydrogen will fulfill a number of crucial functions as a carbon-free energy carrier and "feedstock" for the process industry – i.e. the green production of plastics, steel, paper, paint, fertilizer, food and medicines, among others – as a carbon-free fuel for (heavy) road, water, rail and air transport over long distances (which is not possible with batteries), and as a carbon-free medium for energy storage and transport.

Large energy companies such as Shell, BP and ExxonMobil are committed to making hydrogen production more sustainable, initially by capturing the emissions and transporting them via a pipeline to store them in empty gas fields under the North Sea.

However, this "blue" hydrogen production is an interim solution on the way to the only truly sustainable solution: "green" hydrogen production from (sea)water through electrolysis, where the necessary electricity and heat are generated by sun and wind. To make this possible on a large scale, electrolyzers must become cheaper, which requires innovation and mass production.

Few in the Netherlands and Europe have as much and as deep knowledge and experience in the field of electrolysis as Nobian. Nobian, together with

> Nobian has extensive experience in the field of electrolysis and is thus an essential knowledge partner for the production of green hydrogen

Nobian has extensive experience in the field of electrolysis and is thus an essential knowledge partner for the production of green hydrogen. Hydrogen is currently still produced mainly from natural gas and through a reaction with steam, which is also usually generated with natural gas. The Netherlands is the second largest producer in Europe of this so-called "grey" hydrogen [P].

Macquarie's Green Investment Group, established the Hydrogen Chemistry Company ("HyCC") in 2021 to set up and scale up electrolysis capacity for green hydrogen in the Netherlands and beyond, largely building on Nobian's electrolysis knowledge.

Nobian also plays an important role in realizing the storage capacity required for hydrogen. A major challenge of the energy transition is storage and

[O] Dutch Climate Agreement (2019).
[P] Energy Topsector (May 2018): Outlines of a Hydrogen Roadmap.

transport of carbon-free energy from renewable sources. When energy is needed, the sun does not always shine and the wind does not always blow; when energy demand is lower, there may be ample sun or wind – but sun and wind cannot be stored and used later, unlike oil and natural gas.

Depending on the future scenario, in 2050 the Netherlands will need hydrogen storage capacity for 10-36 TWh of energy[Q].

This could be done in above-ground tanks (although storage volumes are very limited), in empty salt caverns, or in empty gas fields. The latter, however, is not yet technically (due to porosity and hydrogen leakage) or economically feasible, and moreover has not yet been proven safe for the storage capacity required in the medium term. The safety and technical feasibility of storing large volumes of hydrogen in gaseous form in empty salt caverns on land has already been proven and applied in practice [R].

Another important advantage of salt caverns is that they are suitable both for long-term storage (such as seasonal storage or for maintaining buffers) and for (short term) balancing of variations between energy supply and demand. Salt caverns are therefore seen by experts as an important part of the required hydrogen storage capacity.

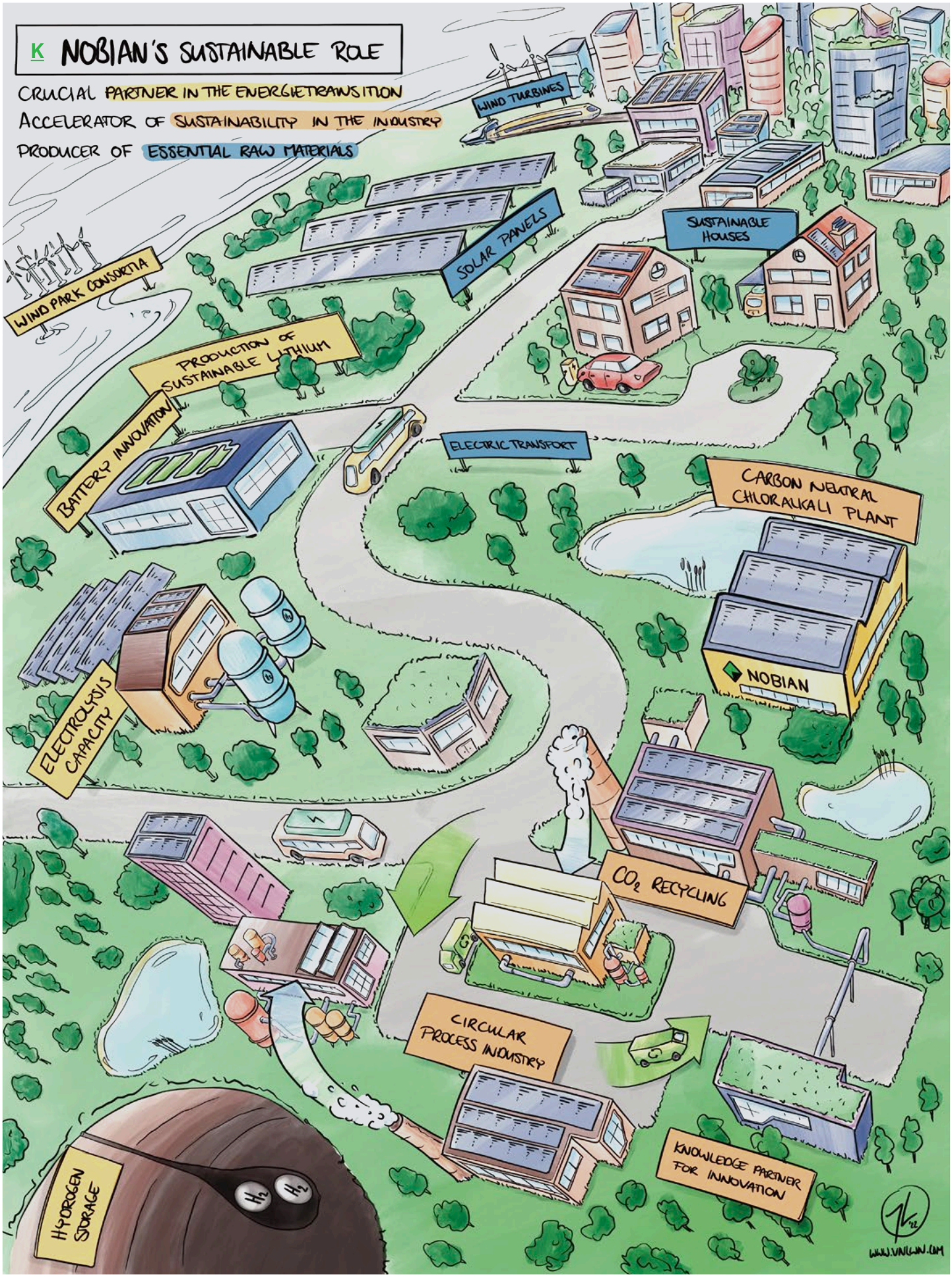
According to experts, the risks of storage in salt caverns are limited and well manageable – provided, of course, that caverns for storage are made suitable and used by a party that knows what it is doing. Nobian has the knowledge and expertise to develop caverns suitable for hydrogen storage. The storage of natural gas in caverns has been done in the Netherlands for decades, and there is already a great deal of experience with the storage of gases in salt caverns specifically constructed for this purpose. In addition, there is a strict permitting process that oversees the safe design of caverns for hydrogen storage.

Salt caverns will be an essential part of a wider range of storage methods for green hydrogen and thus play an important role in helping to realize the hydrogen ambitions of the Netherlands [R]. Depending on the future scenario, in 2050 the Netherlands will need between 45 and 165 salt caverns for hydrogen storage if salt caverns are the only storage option used [T].

According to its own expectations, Nobian can have 60 caverns ready for safe and responsible storage by this point – and thus play a crucial role in a successful hydrogen and energy transition. In order to have the necessary capacity available for underground hydrogen storage, it is important that construction can begin in a timely manner. It is also important that societal concerns regarding the use of salt caverns for hydrogen storage are addressed.

Figure K illustrates the role Nobian plays in the energy transition and in making Dutch society and industry greener. → K

[Q] Roland Berger analysis of TNO study (2021): Underground energy storage in the Netherlands 2030-2050.
[R] The use of salt caverns for natural gas storage is already common practice, and the storage of hydrogen in underground salt caverns is taking place at a number of sites in the United States.
[S] Roland Berger analysis.
[T] Roland Berger analysis.


NOBIAN'S SUSTAINABLE ROLE
CRUCIAL PARTNER IN THE ENERGIETRANSITION
ACCELERATOR OF SUSTAINABILITY IN THE INDUSTRY
PRODUCER OF ESSENTIAL RAW MATERIALS
WIND TURBINES
SOLAR PANELS
SUSTAINABLE HOUSES
WIND PARK CONSORTIA
PRODUCTION OF SUSTAINABLE LITHIUM
BATTERY INNOVATION
ELECTRIC TRANSPORT
CARBON NEUTRAL CHLORALKALI PLANT
NOBIAN
ELECTROLYSIS CAPACITY
CO_2 RECYCLING
CIRCULAR PROCESS INDUSTRY
KNOWLEDGE PARTNER FOR INNOVATION
HYDROGEN STORAGE
H_2
H_2
WWW.VANLWN.COM

5. Conditions for success

The Netherlands has good and compelling reasons to continue salt mining in and for the Netherlands and Europe, and can set clear conditions to ensure safety and sustainability

Salt mining from our own soil offers the Netherlands (and more broadly, Western Europe) security of supply of a crucial raw material for industry and society, and makes it strategically independent of other countries for the production of essential materials for the economy and the energy transition.

Salt mining in the Netherlands is also an economically attractive and sustainable option. There is insufficient capacity in the short term to extract salt from other places in Europe. The import of salt from regions beyond Europe is also a less sustainable alternative. In the long term, retaining domestic salt production is the most sustainable option for chemical clusters in Northwestern Europe. Furthermore, keeping salt production and chlor-alkali production in the Netherlands will safeguard prosperity and employment in the Netherlands and Western Europe, both at Nobian itself and in the chemical industry that depends on Nobian and its suppliers.

With Nobian, the Netherlands has a company with highly pertinent expertise and an expressed and demonstrated willingness to take (joint) responsibility for not only its own operations but also the sustainability of Dutch industry and society as a whole. Nobian can also play an important role in the energy transition and in getting the Netherlands "off natural gas". For example, the company has essential competencies that can be leveraged to facilitate hydrogen production and storage capacity.

To ensure that salt mining in the Netherlands can continue in an effective, sustainable and socially acceptable manner in the long term, we have identified a number of conditions for success. For example, the Netherlands can set clear conditions for Nobian with regard to conducting safe, sustainable and responsible operations and maintaining a transparent dialogue about risks and mitigations.

The government can also support Nobian's ability to run its core operation effectively and in realizing the acceleration of the company's sustainability agenda.

Considering these success factors, the Netherlands has good and compelling reasons to retain salt mining in the Netherlands for its own and Europe's benefit.

Conditions for success

Public conditions for Nobian

1. Focusing on **safe and responsible operations**, in full transparency about risks and mitigations
2. Maintaining a **proactive and transparent dialogue** with local communities, politicians and government, as well as with all relevant stakeholders and interest groups
3. Investing in **making its own operations more sustainable**, with the primary target of having a 100% carbon-neutral operation by 2040

Required government support for salt production

4. Renewing and continuing to grant **salt mining licenses in the Netherlands**, where the government can set clear conditions for (continued) safe and sustainable operations that Nobian can guarantee, with the standard supervision of SodM
5. Acknowledging the **social importance of salt mining** in and for the Netherlands, as well as distinguishing between the limited aboveground impact of salt mining and the minimal risks of subsidence compared to other forms of mining and extraction

Required government support for Nobian's sustainability agenda

6. Public co-financing – where possible and sensible – of **Nobian's emissions reduction program** to further accelerate emission reduction targets
7. Developing **"fit-for-purpose" legislation and regulation** that make energy transition projects possible and facilitate accelerated permitting processes for new and innovative technologies
8. **Stimulating** the development of a **(green) hydrogen market** in the Netherlands, including the infrastructure needed for it (e.g. for storage and transport)

Contact

ERWIN DOUMA
Partner
+31 20 7960609
erwin.douma@rolandberger.com

JORIS WINKELMAN
Project Manager
+31 20 7960609
joris.winkelman@rolandberger.com

BENNO VAN DONGEN
Senior Partner
+31 20 7960607
benno.vandongen@rolandberger.com

TIJO COLLOT D'ESCURY
Managing partner
+31 20 7960613
tijo.collotdescury@rolandberger.com

PUBLISHER:
ROLAND BERGER BV
Strawinskylaan 581
1077 XX Amsterdam
The Netherlands
+31 20 7960600

Cover photo 895606090 / iStockphoto