

# RESEARCH & INNOVATION



TRANSMISSION AND STORAGE  
**2021 REPORT & OUTLOOK**

## WHY THIS REPORT?

This document is Teréga's fifth report on its Research and Innovation (R&I) activities. It provides an overview of the strategic programmes our teams are currently working on in accordance with the IMPACTS 2025 corporate plan. This report details the work undertaken by Teréga SA on regulated gas transport and storage activities, all of which are supported by the French Energy Regulation Commission (CRE).

As a real driving force in the energy transition, Teréga has provided exceptional expertise in the development of gas transport and storage infrastructures for more than 75 years. Its network across south-west France, at the crossroads of major European gas flows, includes more than 5,000 km of pipelines (15.7% of the French gas transmission network) and two underground storage facilities (25.4% of national storage capacity). The company achieved a turnover of €488 million in 2021 and has approximately 650 employees.

## TRANSITION(S) ACCELERATOR

The current situation poses twin challenges with global repercussions: the energy transition and digital transformation. Against this background, innovation is clearly a major priority for Teréga in order to ensure the long-term future of the company as a gas infrastructure operator and a powerful accelerator of the energy transition.

The IMPACTS 2025 corporate plan is therefore underpinned by Research & Innovation, which should allow the company to achieve its ambitions in tomorrow's energy landscape. This plan is structured around five key strategic priorities:

- Providing commercial proposals and satisfying our customers
- Improving efficiency and accountability
- Raising the profile of the company
- Accelerating our development and transforming our infrastructures
- Reinventing Teréga's DNA

Two key initiatives result from this: PARI 2025 (Prevention of Industrial Accidents and Risks), which has a target of "Zero accidents, Zero snagging, Zero surprises", and BE POSITIF (Positive Environmental Assessment), through which Teréga is contributing to France's carbon neutrality strategy for 2050. All company employees are encouraged to contribute to the success of these programmes, as well as to the overall innovation approach, so that everyone can be acknowledged as a contributor to delivery of the corporate plan. Teréga is also committed to inviting its entire ecosystem to play a full part in developing its strategic priorities.

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# Editorial

## Cécile Boesinger



Head of R&I in the Teréga Strategy, Innovation and Development Unit

**“The energy industry faces unprecedented challenges in meeting its energy transition goals.** In practical terms, the energy system must evolve towards a low-carbon, renewable, diversified and decentralised energy mix, and move away from being a vertically structured system dominated by fossil fuels. Gas in general, and the infrastructures operated by Teréga in particular, are central to this process of change, and innovation is an essential factor in the successful delivery of this transformation.

**Its IMPACTS 2025 corporate plan sets out Teréga’s commitment to being a key facilitator of this energy transition.**

Research & Innovation is integral to this framework at two levels:

- adapting infrastructures to accommodate the arrival of new gases (biomethane, methane syngas and hydrogen) by focusing work on their quality, the definition of acceptance thresholds, the management of new flows, etc., in order to meet our customers’ needs;

- developing Smart Multi-Energy Grid projects that promote synergies between energy carriers (electricity, methane, heat, hydrogen, etc.) and their infrastructures, in order to meet the triple energy transition objective, namely the improvement of energy efficiency, the reduction of greenhouse gas emissions and the integration of renewable energies. The flexibility and adaptability of gas transmission and storage infrastructures make this resource a central link in tomorrow’s energy system.

**Naturally, continuous improvement initiatives remain key priorities** for assured service continuity, security of supply and enhanced corporate responsibility.

This mission allows R&I to research and explore any new technology, technique or method with the potential to improve the integrity of our infrastructures, installation performance, process digitalisation, safety, cybersecurity, energy efficiency as well as environmental protection and contributing to our operational strength.”

# ▷ A CROSS-FUNCTIONAL APPROACH TO BOOST INNOVATION

At Teréga, R&I involves around 60 employees spread over all departments, from monitoring and foresight to the implementation of innovations. This internal organisation - coordinated and managed within the Strategy, Innovation and Development Unit, attached to General Management - is one of Teréga's strengths. It firmly roots innovation at the heart of the company's approach through the IMPACTS 2025 Innovation Plan, an R&I roadmap for 2025 developed in conjunction with Teréga employees which defines eleven programmes for regulated transmission and storage activities. Each programme encompasses a set of projects based around a strategic development or business optimisation theme, linked directly to the company's operational needs.

***"R&I is a permanent commitment! The CRE's support for our R&I work is sustained thanks to a robust and efficient management system and convincing results. They allow us to assert our position as an exemplary operator and energy transition accelerator."***



Alexy Heduin  
Research and Innovation Officer

## THE 11 INNOVATION PLAN PROGRAMMES IMPACTS 2025



INFRASTRUCTURE INTEGRITY



FAILURE FORECASTING



NETWORK MONITORING AND UNREGISTERED THIRD-PARTY WORK



WORKPLACE HEALTH AND SAFETY



SECURITY AND CYBERSECURITY



STORAGE FACILITY MONITORING



REDUCING OUR GHG EMISSIONS



LOCAL INTEGRATION & ENVIRONMENTAL FOOTPRINT



BIOMETHANE AND METHANE SYNGAS



HYDROGEN



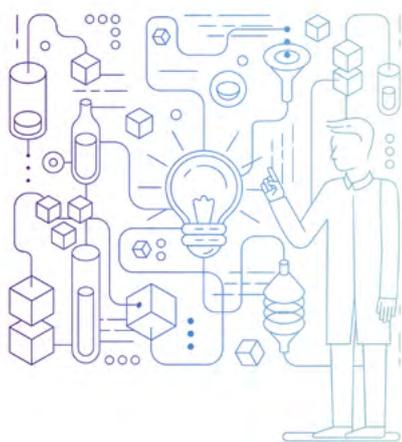
MULTI-ENERGIES

## WHAT DEFINES AN R&I PROJECT?

As an enthusiastic promoter of applied research, Teréga's R&I conducts projects that can be directly deployed in industrial facilities on completion of a development process lasting approximately three years.

The scope of R&I's activity is therefore broad, and covers three main aspects:

- Improving and developing the knowledge and practices of Teréga;
- Testing and building prototypes to qualify technologies and new methodologies wherever feasibility is uncertain;
- Responding to integration issues within its operational environment through the first industrial-scale roll-out.



More than 60 employees  
INVOLVED, WHICH EQUATES TO AROUND 10% OF THE COMPANY'S WORKFORCE.



More than 60 projects  
DIVIDED BETWEEN TRANSPORT AND STORAGE ACTIVITIES.



3 patents  
REGISTERED IN THE FIELDS OF ENERGY EFFICIENCY, GAS QUALITY AND DIGITAL TECHNOLOGY.



More than 40 partners  
WITH COMPLEMENTARY SKILLS.

## Budget indicators:



R&I CAPEX INVESTMENTS  
• €1.4M IN 2020  
• €2.5M IN 2021



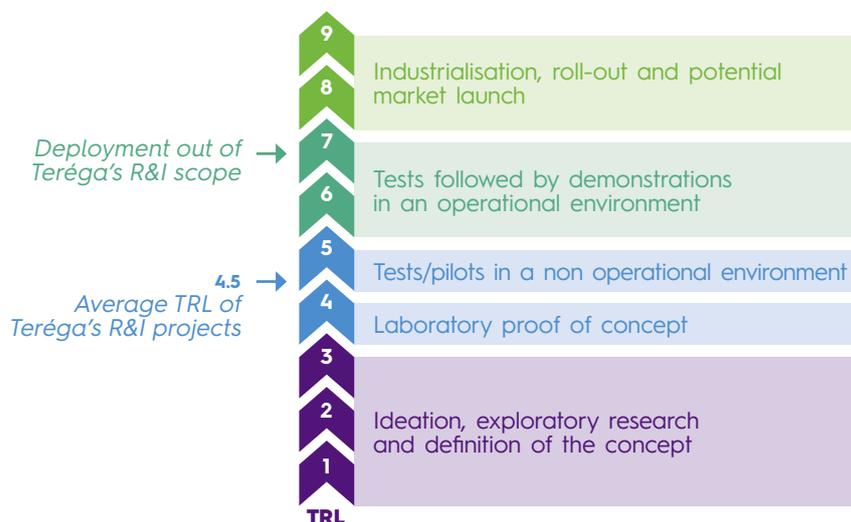
R&I OPEX BUDGETS (2020-2023)\*  
• €8.2M ON ATRT7  
• €2.5M ON ATS2

\* OPEX: Following the update of the R&I OPEX trajectories during the mid-period pricing window at the end of 2021.

## THE TRL SCALE

Teréga monitors the progress of R&I projects using an objective and universally recognised indicator: the Technology Readiness Level (TRL). Most of our projects have a TRL of between 3 and 7.

This indicator is monitored twice a year. Once the feasibility has been validated, the project enters the industrialisation and roll-out phase (TRL 8) and therefore leaves the R&I scope to be coordinated by the relevant business teams.



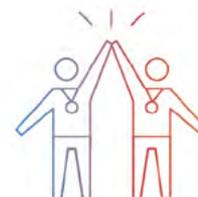
# ▷ A culture of shared innovation at Teréga

For many years, Teréga R&I has implemented and pursued a diverse partnership strategy that has three major goals:

1. **To secure, intensify and develop the knowledge and skills of internal teams** in key technical disciplines by working alongside public and private research organisations, such as the University of Pau and Pays de l'Adour (UPPA) and the National Institute of Applied Sciences in Toulouse (INSA).
2. **To pool efforts** over the long term with other companies from the energy industry (GRTgaz, GRDF, Enagas, Storengy, SNAM, etc.) to address

similar issues, particularly through inter-operator working groups on pivotal topics of major concern to the industry, such as hydrogen injection and the oxygen content of biomethane.

3. **To support the development of innovative technologies or methods**, with the potential to create value for Teréga. These are mainly partnerships with design offices, SMEs or start-ups which facilitate the development of solutions to problems faced by Teréga, help to identify new applications and support industrial-scale development.



## SENGA – A LABORATORY COMBINING ENTERPRISE AND ACADEMIC RESEARCH

In 2021, Teréga and the UPPA inaugurated SENGA, a joint laboratory dedicated to studying the storage of carbon-free gases in aquifers, as an outcome of a long-standing R&I partnership which brings together human, financial and technical resources around a strategic theme for the energy transition. The two partners aim, by 2025, to make this laboratory a competitive and internationally recognised tool in the field of new gas storage in geological reservoirs.

## TENEXI: PROMOTING COLLECTIVE INTELLIGENCE

Teréga, having already been involved in numerous Open Innovation initiatives (CITEPH, the Avenia cluster's Geo Days, etc.), launched its own collaborative innovation initiative in 2020: TENEXI (*Tous ENsemble Explorons l'Innovation*). This initiative has a dual objective:

1. **To launch external calls for projects** to promote the sharing of skills and the development of future industrial solutions. Following an initial campaign focusing on deploying safety solutions to tackle man/machine co-activity risk on worksites, the 2021 campaign identified a solution to detect the potential spontaneous ignition of powdery residues.
2. **To propose internal challenges** to promote the emergence and implementation of relevant solutions from Teréga employees on subjects such as the opportunities to better value mobility or our easement strips, employees' know-how sharing. This approach allows everyone to play a part in the company's development.

*"With TENEXI, we want to harness collective intelligence and involve all our employees and stakeholders in the joint search for innovative solutions, while developing initiative, commitment and the creation of value for the company."*

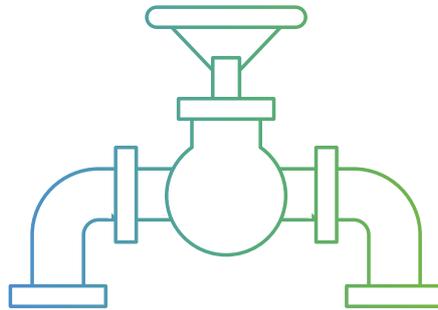


Aurélie Taupin  
Research and Innovation Officer

## INFRASTRUCTURE INTEGRITY

Protecting and inspecting pipelines effectively using the best technologies and methods currently available

OPEX budget:  
42% of the R&I budget  
validated by the CRE for ATRT7



Teréga's status as an operator performing a public service mission imposes a responsibility **to maintain the safety, reliability and availability of its installations**, while optimising network costs and performance.

With more than 5,000 km of pipelines, the integrity of its infrastructures is an essential issue and major challenge for Teréga, highly supported by the PARI 2025 initiative. In this respect, the R&I programme sets out to develop and implement innovative technologies to facilitate **the inspection of inaccessible structures** or respond to regulatory obligations. It also requires the company to constantly improve its knowledge of pipe degradation phenomena and always be **at the cutting edge of the latest techniques for the protection of structures** (coatings, cathodic protection, etc.).

***"R&I's role is to improve pipeline protection and inspection techniques, since these structures present significant technical challenges, such as accessibility, operating conditions, environmental variability, etc."***



Rémi Lancien

Inspection Department Manager  
and R&I "Infrastructure Integrity" Programme Manager

# ▷ R&I projects dedicated to the protection and inspection of pipelines

## 1 – Studying corrosion phenomena to optimise cathodic protection

### THE AIM

The aim of this project is to better understand corrosion factors in order to improve the effectiveness of cathodic protection (CP).

#### The approach

- Studies are being carried out in conjunction with the French Corrosion Institute to determine the efficiency criteria of CP in disturbed environments or particular conditions (type of ground, resistivity, ambient humidity, environment, coupon size, etc.). The performance of new coatings is also being assessed.

- Studies have been conducted with RICE (GRTgaz) to improve assessment of the corrosion risk in the presence of continuous stray currents and to characterise the impact on pipeline protection of a power failure.

#### Benefits

- Improved integrity of gas infrastructures and their extended working life.
- Improved performance criteria of pipe coatings with respect to corrosion risk for future projects.

#### Progress to date

- Characterisation of several calco-magnesian deposits.
- Better understanding of the effect of under-screen corrosion.
- Identification of non-corrosion phenomena for a considerable time without CP.

#### Future developments

- Continuation of the studies (changes to calcium formations, development of a method for characterising the ageing of coatings on-site, determination of conservative protection times in the event of interruption to the power supply, etc.).
- Launch of new studies to continually improve power supply efficiency.

## IMPROVING THE PROTECTION OF OUR STRUCTURES ALSO MEANS...

R&I is also looking at new solutions to complement existing protection technologies.

To protect certain sensitive or difficult-to-reach structures, Teréga is testing the use of VCIs (volatile corrosion inhibitors) to find out whether they can be used effectively against corrosion, particularly in ducts.

The R&I teams are also developing solutions to address the icing of pipelines downstream of delivery stations when expansion causes sudden cooling of the gas. To solve this problem, which can cause operational difficulties, mechanical constraints or civil engineering deformations, a new "icephobic" coating is being developed with the CANOË platform, an entity specialising in R&D for composites and advanced materials.



Icing of a gas pipeline.

## 2 - Innovating to inspect inaccessible structures or to comply with regulatory requirements

### THE AIM

With this project, the ambition of R&I is to identify the best solutions for inspecting points in the network where conventional technologies cannot be used, such as small-diameter unpiggable pipelines, ducts, special lead-throughs in structures or in the open air (TSOA – *traversées spéciales sur ouvrages ou à l'air libre*). In addition to this is the development of technologies addressing the new demands of the Multi-fluid Decree (AMF – *Arrêté Multifluide*) of July 2020, which requires searches to be conducted for all types of structural cracks.

### The approach

- A new non-destructive pipe inspection technology (the magnetic tomography method) is currently being developed and tested in conjunction with Skipper. These advances are being carried out and exchanged in partnership with GRTgaz.
- A duct analysis and sampling model has been developed. Out of Teréga's 5,000 unpiggable ducts, it initially enabled identification of 224 ducts for priority inspection over a 10-year period.
- A collaboration is under way with piston inspection service providers to speed up work on developing new technologies to search for all types of cracks, as none currently exists.

### Benefits

- Control over the integrity of structures for optimal cost.
- Extension of the service life of pipelines and better identification of those requiring enhanced inspection.
- Compliance with regulatory requirements.

### Progress to date

- Improvements to the algorithms used to identify defects using magnetic tomography, although Teréga is suspending the development of this technology as the results are still insufficient.
- Continuation of the duct inspections provided for in the 10-year plan in order to confirm the model developed.
- Study of the sensitivity of pipes to cracking and establishment of a dedicated specification.

### Future developments

- Testing of a new magnetic tomography technology in collaboration with GRTgaz.
- Feedback on completed duct inspections in order to adjust the model. Establishment of a new sampling of ducts for priority inspection.
- Finalisation of the specification on the risk of cracking in accordance with the future GESIP guide and testing of new instrumented pistons to detect cracks.

## WHAT RESOURCES ARE AVAILABLE FOR PIPELINE PROTECTION AND INSPECTION?

In addition to special external coatings, underground pipelines are protected against corrosion using cathodic protection devices. This technique involves applying an electrical voltage to the metal outer surface of the pipe to significantly reduce its potential for corrosion. Regular inspections are also necessary to characterise pipeline conditions and/or coatings as accurately as possible.

These operations are an essential part of ensuring network integrity. For this purpose, Teréga uses a number of complementary techniques:

- Inspection by measuring electrical parameters to detect defects in external coatings
- Inspection by instrumented scrapers to detect losses of metal and/or distortion of the buried structure;
- Excavation to allow visual inspection of a predefined area.

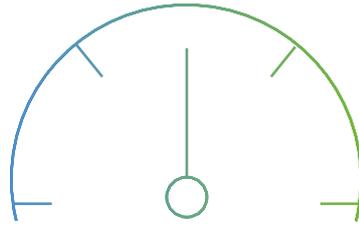


Pipeline with indication of defects.

## OPERATIONAL PERFORMANCE AND SAFETY

Improving network monitoring and maintenance means exploiting the capabilities of digital technology

OPEX budget: 4% of the R&I budget  
validated by the CRE for ATRT7  
R&I CAPEX budget: €0.3m in 2020  
and €0.5m in 2021



As a key player in the gas industry, Teréga has a clear responsibility to deliver **operational excellence in complete safety** to ensure the unfailing availability and reliability of its facilities. This essential and non-negotiable priority is central to the PARI 2025 “Zero Accident, Zero Snagging, Zero Surprises” programme. R&I is therefore working on two programmes: **network monitoring and forecasting of any failures or breakdowns affecting the facilities.**

These projects often rely on the new opportunities offered by digital transformation (big data digital architectures, connected objects and artificial intelligence), with the aim of setting up an Intelligent System for Monitoring Structures (SISO – *Système Intelligent de Surveillance des Ouvrages*) allowing real-time supervision of the network.

***“R&I has a two-fold mission in terms of network monitoring: to improve the aerial surveillance solutions currently in place and to develop a real-time detection solution for undeclared third-party work.”***



Natacha Merlet

EI2A (Electricity, Instrumentation, Automation and Analysis) Manager and R&I “Network Monitoring and Undeclared Third-Party Work” Programme Manager

***“It is through the implementation of optimal predictive maintenance on our critical installations that Teréga will not only be able to be alerted when a malfunction occurs, but also, thanks to artificial intelligence, provide a diagnosis of the probable causes of their failure.”***



Ludovic Jobin

Compression and rotating machinery engineer and R&I “Failure Forecasting” Programme Manager

# ▷ R&I projects that harness the power of digital for the benefit of the network

## 1 - Improve aerial surveillance of the network

### THE AIM 5-6 TRL

This R&I project aims to improve and automate aerial monitoring of the network, which is currently carried out by fixed-wing aircraft or helicopter.

The wider ambition of this project is to avoid the risks associated with undeclared third-party work, urban development, invasion by vegetation or landslides.

#### The approach

- A new aerial surveillance technique is being tested with Thales using long-distance drone overflights.
- Proofs of Concept (POCs) have been launched for implementation of a monitoring solution optimised through the use of satellite images (change detection by comparing successive images taken at the same place).
- Automation of data processing is being studied to provide reliable and real-time alerts.

#### Benefits

- Optimisation of the security and reliability of monitoring, traceability of anomalies (auditable system).
- Increased monitoring frequency.
- Reduction in the environmental footprint by eliminating plane and helicopter overflights.

#### Progress to date

- First drone overflight tests over a distance of 40 km (autonomous but monitored flight, without elevation or habitation) and preparation of subsequent tests (autonomous flight, longer distance, tougher environment, potential automatic anomaly detection).
- Completion of two network monitoring POCs with two satellite image processing companies.

#### Future developments

- Resolution of regulatory issues with drone overflights.
- If the POCs are conclusive, development and qualification of an operational demonstrator with automatic satellite image processing algorithms.

## TERÉGA TESTS DRONE MONITORING

Since 2020, Teréga has been working with Thales to study the implementation of a network monitoring solution using long-distance drones, in compliance with French and European flight regulations.

This solution aims to improve the monitoring of out-of-sight infrastructure, as well as to reduce the environmental impact and cost of operations by limiting the use of planes and helicopters.

The technologies tested must allow safe and secure tracking and control of the drones in the restricted space of the Teréga network and automatic processing of the images captured.



## 2 - Developing real-time network monitoring

### THE AIM

This project aims to establish new solutions for detecting risks affecting buried structures, in addition to aerial surveillance technologies.

#### The approach

- A new three-in-one fibre optic measurement technology (combined temperature, distortion and acoustic measurements) has been developed with the startup Febus Optics and in partnership with TotalEnergies and SAIPEM.
- Studies are being conducted to establish an intelligent surveillance network using autonomous sensors built into terminals/markers installed along the network.

#### Benefits

- Better remote detection of attacks on pipes for guaranteed safety.
- Faster response times for a higher level of service continuity.

#### Progress to date

- Creation of a test bench to simulate risk events and build a database of signals acquired by optical fibre. Development of an event classification algorithm.
- Labelling of the smart terminals/markers project by the strategic committee for the French water sector and validation of the financing by Bpifrance.

#### Future developments

- Completion of tests to detect undeclared third-party work on an existing pipeline in collaboration with several providers of fibre optic measurement analysis. If these are conclusive, selection of the best supplier and decision to implement on certain structures.
- Development of smart markers on registered worksites ahead of potential operational roll-out.



Network signalling marker in Rion-des-Landes.

## 3 - Forecasting failures in our critical facilities

### THE AIM

This R&I project aims to optimise the use of data from industrial equipment using artificial intelligence, in order to increase the safety of certain critical facilities.

#### The approach

- Development of a two-in-one solution for detecting gas leaks and forecasting breakdowns in the delivery stations' expansion valves.
- Exploration of predictive maintenance solutions, particularly on compressors, thanks to digital assistance based on physics and statistics.
- Experimentation with the IoT Valley of sensors equipped with artificial

intelligence to provide a better understanding of the complex and random vibrations of the storage surface infrastructures.

#### Benefits

- Reduction of operational risks.
- Reinforcement of the security of critical facilities.

#### Progress to date

- Installation of the two-in-one solution on a first delivery station.
- Installation of predictive maintenance modules based on the analysis of electrical current harmonics on pumps and compressors.
- Sourcing and initial installation of vibration sensors and an analysis solution adapted to storage

according to the various configurations of the injection and extraction network.

#### Future developments

- Failure tests on the delivery station equipped with the two-in-one solution.
- Implementation of global monitoring of compressor vibrations for predictive maintenance on one or more sites.
- Roll-out of sensors for vibration monitoring of storage infrastructures.
- Study of the industrialisation of solutions with a view to their roll-out.

## MONITORING OF UNDERGROUND STORAGE FACILITIES

Ensure rigorous and controlled management of these geological structures

OPEX budget: 34% of the R&I budget  
validated by the CRE for ATS2  
R&I CAPEX budget: €0.2m in 2021



Because Teréga is a major player in the security of energy supply in France, an essential dimension of its activity lies in the **proper operation of its two underground aquifer storage facilities, Lussagnet and Izaute**. These account for 25% of French storage capacity, or the equivalent of several dozen days of national consumption. This requires the very best monitoring methods and technologies to guarantee rigorous and controlled management of these underground structures, as part of a continuous improvement process. This programme harnesses Teréga's geoscience expertise **to enhance the safety, reliability and availability of its storage facilities**.

***"Teréga's gas storage facilities are of indisputable strategic importance. It is our responsibility to provide operators with the best tools to operate in complete safety."***



Pierre Chiquet

Head of the Geosciences Department and R&I  
"Underground Storage Monitoring" Programme Manager

# ▷ R&I projects devoted to the performance and integrity of underground storage facilities

## Using cutting-edge technologies to check for leaks from storage facilities

### THE AIM

This R&I project involves the development of efficient and reliable monitoring solutions to assess the seasonal effects of gas injection/extraction more accurately, monitor the water/gas interface from the surface, and ensure the integrity of the geological structure above the storage aquifer and its boreholes. Teréga is also working on an industrial and environmental monitoring system for gases in the atmosphere, the sub-soil and directly above storage facilities.

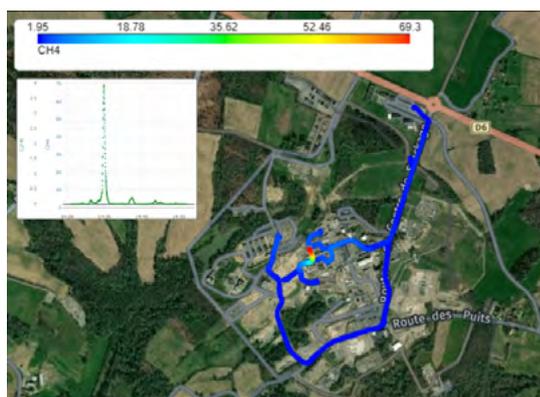
### The approach

Various monitoring techniques are explored before being rolled out operationally:

- Participation, alongside Storengy and Géolinks, in the development of a passive seismic monitoring solution using ambient noise to detect the movement of fluids deep underground.
- Development with IFPEN of a solution using specific sensors and analysers for real-time measurement of gas emissions so as to detect composition anomalies at ground level or in the ambient air.
- Implementation of geochemical tools with the UPPA to improve characterisation of annular gases, monitor BTEX biodegradation mechanisms and improve interpretation of analysis results.
- Development and installation of analysers on the outskirts of the storage facility to measure the atmospheric concentration of odorous molecules (particularly THT) in order to meet regulatory obligations and reduce odour pollution for local residents.

### BIOGENIC OR THERMOGENIC?

Methane ( $\text{CH}_4$ ) emissions around storage facilities can come from various sources. Gas from gas infrastructure is referred to as having a thermogenic origin. Methane can also be produced by the natural decomposition of organic matter, referred to as having a biogenic origin. This is why it is important to be able to characterise the gases, in order to diagnose the origin of the emissions and detect potential leaks (i.e. when the gas has a thermogenic origin).



Geographic representation of  $\text{CH}_4$  emissions and their concentrations at the Lussagnet site.

On-board analyser on a vehicle as part of soil gas analysis campaigns.



## Benefits

- Reinforcement of the integrity of Teréga's underground storage facilities.
- Guarantee of better acceptability of Teréga's storage activities.

## Progress

- Launch of work via the CITEPH on passive seismic monitoring: establishment of listening coverage over a radius of 6 km around the Lussagnet storage facility.
- Completion of four soil gas analysis campaigns and improvement of analysis techniques to determine the origin of the gases: no emissions at soil level, identification of low diffuse losses from some surface facilities.
- Preparation of a thesis within the framework of the SEnGA joint laboratory and completion of the first water/gas sampling to expand the database.
- Development and testing of the first THT analysis prototypes before installation on-site.

## Future developments

- Qualification of the capacities of the Géolinks technology to track the movement of gas and water within the coverage area and possible continuation of the CITEPH project.
- Operational implementation of soil gas monitoring via analysis campaigns every two or three years.
- Launch of the thesis on the implementation of operational geochemical tools for monitoring the storage of natural gas in aquifers and potential application to hydrogen blends.
- Installation of the first prototypes for the analysis of THT and other odorous molecules, testing and improvements.

## STUDY OF SOIL MOVEMENTS BY SATELLITES

In order to study the potential impact of the seasonal effects of gas injection and extraction, Teréga's R&I teams have also developed a device for monitoring soil movements and terrestrial surface variations. A technology has been in development with TRE Altamira since 2014, involving a constellation of satellite reflectors on the ground allowing the use of a radar interferometry solution. Since the technology has been deployed operationally, the deformations observed are of very low amplitude (max. 8 millimetres) and demonstrate the low surface impact of gas storage operations.

## UNDERGROUND STORAGE: A STRATEGIC LINK IN THE GAS ENERGY CHAIN

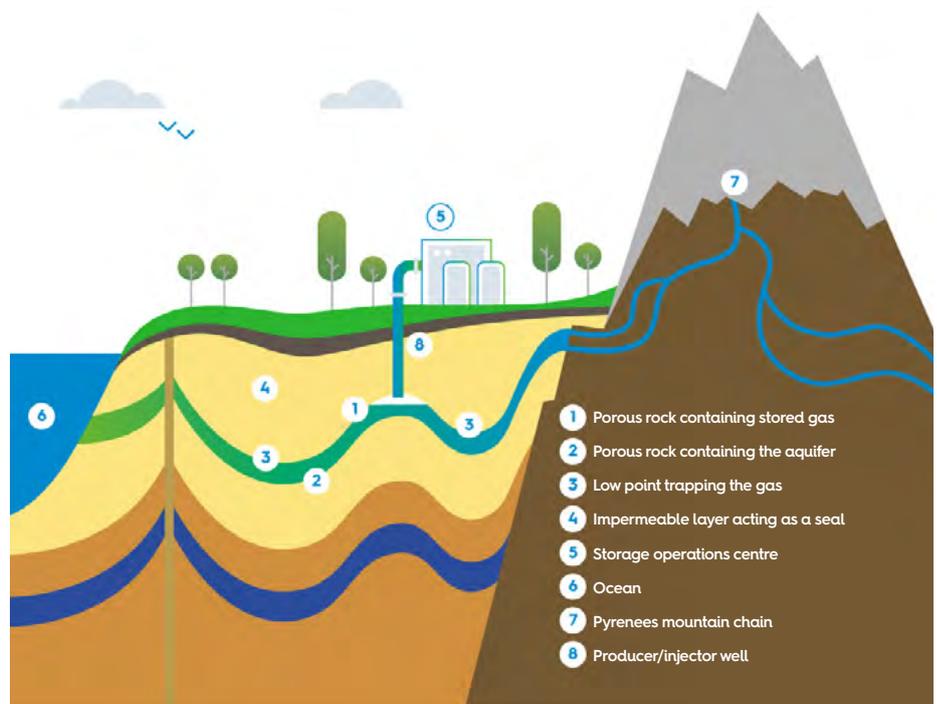
Underground gas storage is used to meet seasonal variations in demand for natural gas. It provides an efficient and economical technical solution for the security of the national supply and to respond to fluctuations during peak consumption periods. Each of the two underground storage facilities operated by Teréga consists of a porous geological layer at depths of approximately 500 to 700 metres. This "reservoir" rock formation is covered by an impermeable "cover" rock formation consisting mainly of clay.

One of the main challenges posed by this type of storage is to reconcile the technical performance it offers gas suppliers with the need to analyse the potential piezometric impacts on facilities operated by other water table stakeholders: the geothermal sector, suppliers of drinking water and water for irrigation, etc. The crucial

element of these infrastructures is monitoring.

In addition to dedicated monitoring boreholes, a full range of precautions is in place to provide

an appropriate monitoring network and measure the potential impact of gas storage on the environment and groundwater.



## PERSONAL SAFETY, SECURITY AND CYBERSECURITY

Efficiency also  
means ensuring  
the safety of people  
and facilities

OPEX budget: respectively 3% and 4%  
of R&I budgets validated by the CRE  
for ATRT7 and ATS2



As a responsible gas infrastructure operator, one of Teréga's main priorities is **ensuring the safety of its field operatives**, as well as of its partners and local residents.

R&I is therefore committed to implementing innovative means **to ensure optimal working conditions, promote a safety culture and prevent risks of accidents.**

At the same time, Teréga is also launching a new R&I programme to **improve security and cybersecurity, in order to prevent malicious actions** that could impact teams, information or property.

Both programmes contribute to essential components of PARI 2025.

***"Safety should be everyone's business, whether on worksites or in offices. This is our common foundation, to which R&I brings an additional dimension."***



Anne Chauvancy

Workplace Health and Safety Engineer and R&I "Workplace Health and Safety" Programme Manager

***"Security and cybersecurity are changing all the time! We need to be at the cutting edge of methods and technologies to identify risks, control them better and anticipate any malicious action."***



Vincent Verquère

Site Operational Safety Officer and R&I "Security and Cybersecurity" Programme Manager

# ▷ R&I projects to enhance safety using new technologies

## 1 - Rolling out innovative solutions to reduce worksite accidents

### THE AIM

Through this project, R&I aims to establish innovative solutions to reduce risks relating to man/machine co-activity on worksites. This is a priority for the company, affecting both Teréga employees and external contributors.

#### The approach

- In collaboration with Reckall, experiments are carried out directly in the field on a system to prevent collisions on worksites between mobile machinery and pedestrians.
- Work is under way with Atouts HSE and ST37 to study the development of a solution for the visual analysis of people and objects on-site using cameras incorporating artificial intelligence algorithms.

#### Benefits

- Reduction of accidents and incidents during the worksite phases.

#### Progress to date

- Finalisation of the first TENEXI Open Innovation call for projects, launched in 2020 by Teréga on working with machinery, which led to the identification of key technology partners.
- Field testing of the Reckall solution on two worksites.
- Launch of a technical feasibility study with Atouts HSE and ST37.

#### Future developments

- Qualification of the relevance of the various solutions before further development.
- Identification of new ideas to improve people's safety.



Excavation of a pipeline on a worksite.

## OPEN INNOVATION TO INCREASE THE SAFETY OF MAINTENANCE OPERATIONS

The second TENEXI Open Innovation challenge, launched by Teréga in 2021, focused on the management of risks associated with maintenance operations and particularly those that regularly reveal residues in the form of powders (when changing filters on sectioning and delivery stations or during pipe pigging operations). These "black powders" have a potential for spontaneous ignition that it is important to be able to detect as soon as they are extracted, in order to take all necessary safety measures.

The winner of the challenge, the company INGEN, proposed a method for differentiating powders by density to confirm the presence or absence of sulphur, a major compound involved in these reactions. This solution will be developed and validated via an R&I project before being rolled out on the ground if testing proves conclusive.



## 2 - Rolling out innovative solutions to protect isolated workers

### THE AIM

With this project, R&I aims to improve the protection of Teréga employees, particularly when they have to work alone or when they are exposed to various risks in the field (falls, encountering wild animals, illness, etc.).

#### The approach

- To protect isolated workers, a collaboration is under way with TotalEnergies and the startup TRAXxs to develop connected insoles capable of detecting a loss of verticality and triggering a call for help or even sending an alert in the event of evacuation.

#### Progress to date

- Launch of the first testing of connected insoles in several scenarios.
- Beginning of the ATEXisation of the solution ahead of field testing.

#### Future developments

- Identification of new ideas to improve people's safety.

#### Benefits

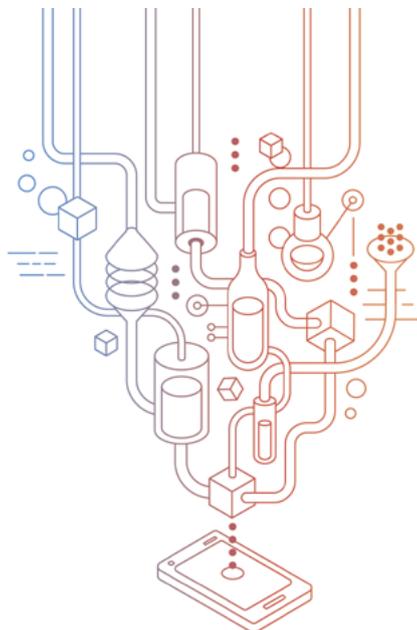
- Improvement of the protection of isolated workers and response to a regulatory obligation.



Prototype connected insole.



Teréga employee working at the Lussagnet storage site.



### IMPROVING THE SECURITY AND CYBERSECURITY OF TEREGA'S ACTIVITIES

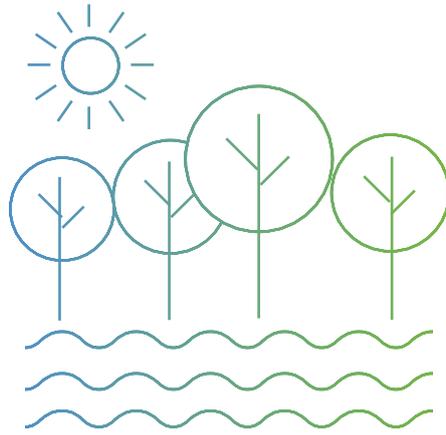
Teréga is also impacted by the increase in malicious actions, particularly involving cyber-attacks. Given the nature of its activities, it has a duty to take direct action to counter these new threats in order to ensure the safety of facilities and the cybersecurity of industrial and IT systems.

That is why the R&I teams have launched a programme dedicated to this new priority, with the aim, by 2025, of deploying innovative solutions to anticipate, control, reduce threats and limit the impact that a malicious act could have on teams, information or assets.

## REDUCING OUR GREENHOUSE GAS EMISSIONS AND ENVIRONMENTAL FOOTPRINT

# Measuring, avoiding, reducing and offsetting impacts

OPEX budget: respectively 9% and 5% of R&I budgets validated by the CRE for ATRT7 and ATS2  
R&I CAPEX budget: €0.2m in 2020 and €1.2m in 2021



As a responsible operator, Teréga pays particular attention to limiting its environmental footprint by applying the ARO method: avoiding, reducing and offsetting the impacts of its activities. All departments and R&I are therefore involved in an ambitious initiative called BE POSITIF, through which Teréga is contributing to France's strategy to be carbon neutral by 2050.



To contribute to this objective, R&I has established two programmes to develop and then deploy **innovative methods to reduce greenhouse gas emissions, improve energy efficiency and reduce impacts on biodiversity**. Research lasting several years has already been conducted, aimed at demonstrating the safety of natural gas storage in the context of the piezometric level and aquifer chemistry – vital actions to facilitate public acceptance of the company's activities.

***"R&I has set itself the twin targets of supporting and improving the local integration of infrastructures and limiting their environmental impact. The programme therefore incorporates several projects directly related to BE POSITIF."***



Laëtitia Mahenc

Head of the Environment & CSR Department, R&I "Local Integration and Environmental Footprint" Programme Manager and BE POSITIF Programme Manager in 2021

***"As a company that has been ISO 50001 certified since 2014, Teréga has made energy efficiency and the reduction of its emissions one of its main concerns."***



Éric Bouley

Processes Department Manager and R&I "Controlling our Greenhouse Gas Emissions and Energy Efficiency" Programme Manager

# ▷ R&I projects to reduce the environmental impact of Teréga

## 1 - Rolling out solutions to reduce methane emissions

### THE AIM

This R&I project is testing a range of different technologies to limit and recover the methane emissions that result directly from network operations, while maintaining the same level of service. Due to its activities, methane emissions are the main source of greenhouse gases (GHG) at Teréga and are therefore the central focus of actions carried out by the R&I teams. Developments focus first on the most significant emissions (venting of compressors, decompression of pipe sections to carry out work or maintenance), then the more minor (particularly detection and reduction of diffuse losses).

#### The approach

- Solutions are being rolled out or have already been implemented to limit venting, the atmospheric release of gas following the shutdown of a compressor or for work on a section of pipeline.
- Studies are carried out to limit diffuse losses from equipment during normal operations (e.g. compressor seals, valves or flanges). The highly disparate nature of these leaks makes them difficult to measure, quantify and recover.

#### Benefits

- Improvement in the responsibility of Teréga, which is significantly shrinking its environmental footprint by meeting and exceeding its legal commitments.

#### Progress to date

- An innovative mobile recompression unit (MOBILE COMP), fully adapted to Teréga's needs, has been built and commissioned. This makes it possible to recover several tens of thousands of tonnes eqCO<sub>2</sub> each year.

- As part of the BEST (low emissions compression stations) project, four recompression units (RECOMP) have been commissioned to recover emissions during station venting. At the same time, an SRGG (seal gas leak recovery system) pilot project has been commissioned to recover gas from the compressor seals. The BEST project will ultimately prevent almost 15% of Teréga's GHG emissions compared with 2019.

#### Future developments

- Launch of studies on the recovery of emissions linked to more moderate decompression.
- Installation and then testing of a new nitrogen-tight seal technology (see inset).
- Comparison of the technical and economic performance of the various solutions before roll out to other compressor stations.



Mobile Comp, the Teréga recompression truck, at work in Urgosse (32).

### NITROGEN SEALS: A SEALING SOLUTION FOR COMPRESSORS?

Diffuse losses are a priority issue for reducing Teréga's GHG emissions. That is why an alternative is also being studied in parallel with the SRGG project: the CobaDGS solution. This is a new nitrogen seal technology, completely eliminating leaks as well as methane emissions linked to the normal activity of the compressors.

## 2 - Pursuing efforts to be a leader in environmental management

### THE AIM

This R&I project aims to test and then roll out solutions to improve Teréga's biodiversity and environmental conservation practices, on worksites and in the operation of facilities. It is important for Teréga to remain proactive in innovation in order to sustain and strengthen the environmental management of its activities.

#### The approach

- More environmentally-friendly solutions are studied to address the use of phytosanitary site maintenance products.
- A methodology called MERCIe (rapid assessment method for ecological impact compensation) has been developed with the University of Montpellier and DREAL Occitanie. This is used to assess the ecological losses and gains resulting from development projects and associated compensatory measures.
- Innovative solutions are studied to make use of easement strips to support biodiversity, as well as offering a vehicle for societal integration.

#### Benefits

- Optimisation of facility maintenance costs.
- Anticipation of regulations and better societal acceptability on the part of stakeholders and local residents.

#### Progress to date

- Beginning of testing of alternative solutions to phytosanitary products, e.g. mineral mulching, sand, lime.
- Launch of an internal innovation challenge on the best use of easement strips.

#### Future developments

- Carrying out additional testing with alternative biocontrol products and roll-out of one or more solutions on Teréga sites if the results are conclusive.
- Testing prior to implementation of the winning ideas from the innovation challenge on the use of easement strips.
- Investigation of new scenarios to reduce the impacts of Teréga's activities.

### R&I AS A VECTOR OF SOCIETAL INTEGRATION

As a manager of subsurface gas storage facilities, Teréga must work on the societal acceptability of this activity. The initial ambition of R&I is to develop and promote innovative methods to encourage the involvement of stakeholders, particularly local communities, in a constructive dialogue around the sectors exploiting underground environments (including with new gases). This approach is embodied by the GÉFISS (extended governance for underground engineering sectors) project.



## R&I TO PROVE THE SAFETY OF UNDERGROUND STORAGE FACILITIES

To control its storage facilities' impact on the aquifer and improve the acceptability of its activities, Teréga conducts two main lines of research.

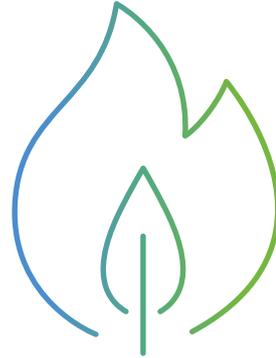
On the one hand, the company has worked for over 20 years with the UPPA and Storengy to demonstrate the safety of natural gas storage in the context of aquifer chemistry. This collaboration, which was completed in 2020, revealed the existence of micro-organisms capable of directly biodegrading certain undesirable natural gas compounds in the subsoil. With the energy transition, new lines of research have been identified to follow up on these studies (particularly since the arrival of biomethane and hydrogen).

In addition, Teréga wanted to better understand the functioning of aquifers in the northern Pyrenees in order to achieve smoother management with the aquifer's other operators (thermal energy, geothermal energy, production of drinking water and irrigation). Several studies involving various Earth sciences disciplines have therefore been launched to advance knowledge of the subsoil. This collaboration, called GAIA, with the Bureau of Geological and Mining Resources (BRGM) and the Adour-Garonne Water Agency (AEAG), has developed modelling and decision-support tools which were then shared in complete transparency, for the benefit of all.

## NEW GASES: BIOMETHANE AND METHANE SYNGAS

Facilitating their  
integration is all about  
working today on the  
energy mix of tomorrow

OPEX budget: respectively 9% and 4%  
of R&I budgets validated by the CRE  
for ATRT7 and ATS2  
R&I CAPEX budget: €0.8m in 2020  
and €0.6m in 2021



Teréga firmly believes that gas is an energy for the future with a key role to play in energy transition. This is why the company continues to **drive initiatives that promote and facilitate the integration of new biomethane and methane syngas in transport and storage infrastructure.**

Indeed, it is a priority to prepare for the increasing arrival of these new gases in existing networks by developing processes such as methanisation, pyro-gasification, methanation or even hydrothermal gasification.

R&I is therefore studying the composition of these new gases to ensure its compatibility with all transport facilities and that it does not pose a risk to the integrity of the underground storage facilities' geological structures. The R&I teams are also involved in collaborative projects to study various renewable gas production processes to ensure the high quality of the gas obtained.

***"We want to be proactive in adapting our infrastructures to the new technologies associated with the renewable gas sectors. This is one of our priority commitments, not only in terms of innovation, but also in terms of our corporate plan."***



Guilhem Caumette

Environment Engineer, Energy Research and R&I  
"Biomethane and Methane Syngas" Programme Manager

# ▷ R&I projects to facilitate the integration of renewable gases

## 1 - Researching the impacts of biomethane on installations

### THE AIM



Teréga is continuing its R&I efforts to promote the injection of biomethane into gas infrastructure by monitoring the long-term impact on transport and underground storage facilities.

#### The approach

- Campaigns to measure biomethane trace compounds are being conducted at injection sites (CARABIO project with GRTgaz, Storengy and GRDF).
- A high-pressure sampling bench and specific analyses are being developed with the UPPA to characterise the trace elements present in biogas and biomethane.
- Corrosion indicators have been installed at Teréga's biomethane injection stations to test the impact of O<sub>2</sub> on the pipework.

- Corrosion tests are conducted in the laboratory to determine the integrity of storage wells in the presence of O<sub>2</sub> (CorrO2 project carried out with the UPPA and Storengy).
- Pressurised aquifer storage conditions are reproduced in the laboratory to assess the effects of different O<sub>2</sub> concentrations on the geological reservoir and subsoil micro-organisms (RINGS-1 project with the UPPA, Storengy, SNAM and Enagas).
- After removal of the corrosion indicators one year and then three years after their installation, no major corrosion impact was observed on the transmission network steels.
- Demonstration of non-zero corrosion rates under Teréga's storage conditions, but which could be compatible with the lifetime of the wells according to initial estimates.
- Finalisation of the RINGS-1 experiments: an impact has been identified on the microbiology of the subsoil at high O<sub>2</sub> levels (1%) under Teréga's storage conditions.

#### Benefits

- Improved integration of biomethane in the network by anticipating potential operational constraints.
- Assurance of gas quality compliant with regulations and technical specifications.

#### Progress

- Out of the 75 measurement campaigns completed, more than 500 compound traces were analysed. No health impact or loss of integrity was identified on the infrastructure.
- Finalisation of the construction of the high pressure sampling bench and co-filing of a patent for the sampling cartridge. Use of the bench for campaigns to measure metals in gas.

#### Future developments

- Continuation of campaigns to analyse new biomethane injection sites.
- Interpretation of experiments complementary to RINGS-1 with lower levels of O<sub>2</sub> in order to enhance understanding of potential impacts.
- Preparation of subsequent RINGS-1 experiments with the launch of a new thesis (RINGS-2).
- Launch of work on deoxygenation (see inset).

### REDUCING THE O<sub>2</sub> CONTENT OF BIOMETHANE

Biomethane has higher oxygen levels than natural gas. This is the main corrosion factor present in biomethane, strongly associated with biogas desulphurisation techniques. Technologies must therefore be found to control its content in the gas chain. Network and storage operators GRTgaz, GRDF, Storengy and Teréga have joined forces to consider this technical issue and have launched an Open Innovation call for projects in order to identify innovative operational deoxygenation solutions for roll-out from 2024.



CorrO2 project corrosion test bench in the UPPA laboratory.

## 2 - Studying the quality and impacts on facilities of methane syngas

### THE AIM



This project is expanding R&I's knowledge of the various methanation processes (biological, catalytic, etc.). The objective is to carry out a technological, economic and regulatory assessment of these processes with the potential to contribute to multi-energy Smart Grids. By participating in various collaborative projects in its region, Teréga promotes the development of renewable gas production sectors locally.

### The approach

- Experimental studies (process performance, environmental impacts, gas composition, etc.) are being conducted with GRTgaz, Storengy and GRDF on the semi-industrial pyro-gasification site of the GAYA platform in Saint-Fons.
- Various innovative methanation projects have been launched with Teréga's participation (see SOLIDIA platform box).

### Benefits

- Promotion of synthetic methane injection and development of expertise in gas quality.
- Optimising biomethane production through solutions for recovering energy from CO<sub>2</sub>.

### Progress to date

- Electrolytic hydrogenation project (SOLARVI): continuation of laboratory testing with the first molecules of H<sub>2</sub> produced, encouraging results and optimisation of the pilot prior to methane production.
- Biological methanation project (DEMETHA): launch of laboratory studies and pilot design.
- Solar renewable methanation project (MARS): identification of key reaction mechanisms and development of various reactor designs.
- Catalytic methanation project (METHAMAG): project launch and pilot design.
- More advanced biological methanation project (CO2METH): abandoned as the project is not economically viable.

### Future developments

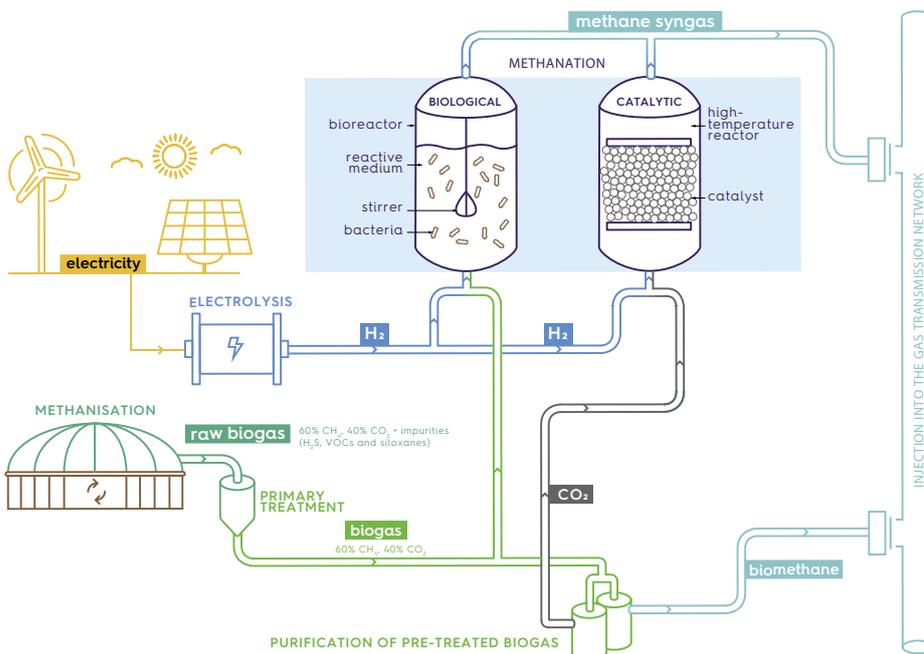
- Finalisation of testing on the GAYA platform.
- Construction of the SOLIDIA platform and installation of the DEMETHA and METHAMAG pilots to begin testing.
- Technical and economic qualification and consideration of conducting larger-scale demonstrators for the MARS and SOLARVI projects.



### THE SOLIDIA PLATFORM, A LAND OF PILOTS...

Located in the heart of Teréga's region, in Bélesta-en-Lauragais (31), the SOLIDIA platform aims to host pilots for new biogas purification, methanation and gas quality control technologies. Directly connected to the arrival of biogas from the Cler Verts methanisation site, this should enable the development of the renewable gas sector. SOLIDIA will be run by INSA in Toulouse, which will have access to Teréga's gas infrastructures construction and operation expertise, essential to the success of a project on this scale. Construction will begin in 2022.

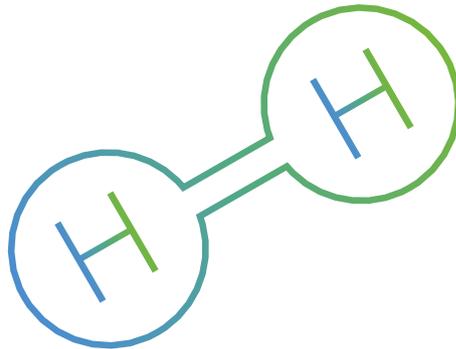
## BIOMETHANE AND METHANE SYNGAS



## HYDROGEN

# Participating in the development of a new energy carrier

OPEX budget:  
respectively 23% and 31%  
of R&I budgets validated  
by the CRE for ATRT7 and ATS2



Because Teréga wants to support national and European strategies relating to carbon-free hydrogen, a large number of R&I projects are being carried out to facilitate the integration of this new molecule into the gas network, in a mixture with natural gas or, in the longer term, via dedicated pipes. The studies mainly focus on the **hydrogen compatibility of existing transport and storage infrastructure**, but also associated equipment and processes. This work should lead to a definition of the conditions of acceptability, the potential technological obstacles to be resolved and the possible adaptations to be considered to support the development of the hydrogen carrier. Teréga's proactive approach in this area is essential to help achieve carbon-free energy by allowing reliable and secure circulation of hydrogen between producers and consumers, whether in France or across Europe.



***“R&I is the cornerstone of the essential first phase of studies, calculations, trials and tests which will enable us in the future to inject, transport and store hydrogen in our infrastructures in complete safety.”***

Émeline Quarin

Hydrogen studies coordinator

# ▶ R&I projects to promote the integration of hydrogen into gas infrastructure

## 1 - Researching the impacts of injecting blended hydrogen into transport facilities

### THE AIM



This R&I project aims to characterise the potential impacts of injecting H<sub>2</sub> into Teréga transmission infrastructures in order to identify areas suitable for injection, the optimum blending rate with natural gas and the adaptation of gas specifications.

### The approach

- Studies and tests are being conducted on the H<sub>2</sub>/natural gas mixture in order to better understand its impact on the integrity and metallurgy of existing pipelines.
- Tests are being conducted to forecast the H<sub>2</sub> compatibility and sealing capacity of equipment, gas equipment and related infrastructure.
- High level of contact and interaction with other French and European gas operators have been set up (regulatory and technological monitoring, definition of common acceptability criteria, feedback sharing).

### Benefits

- Control of the quality of the gases injected and study of the associated impacts.
- Anticipation of potential operational constraints.
- Preparation for future requests from customers to inject/transport H<sub>2</sub> through Teréga's pipelines.

### Progress to date

- Mapping to visualise the compatibility of the pipelines by acceptable H<sub>2</sub> thresholds and according to the MSP (Maximum Service Pressure).
- Continuation of integrity testing at different H<sub>2</sub> concentrations with the Prime Institute (resistance, crack propagation, etc.).
- Launch of leakage testing of various equipment, particularly on a helium test bench developed by Teréga and through a CITEPH collaborative project with CETIM (project co-financed with ENGIE, Storengy, GRTgaz, SAIPEM, TotalEnergies and Cameron France).

- Launch of research into the performance of other gas equipment in collaboration with the various suppliers (particularly compressor manufacturers). Numerous other contacts/tests are being performed in order to conduct a thorough review before adequate conclusions can be supplied regarding network compatibility.

### Future developments

- Launch of a project to test gas equipment in the presence of H<sub>2</sub> on the FenHyx platform with GRTgaz.
- Finalisation of the various tests and trials, sharing with other operators, publishing recommendations and defining acceptable H<sub>2</sub> concentrations depending on network conditions.
- Development of mitigation solutions and/or new equipment if necessary.

## OPERATORS JOIN FORCES ON THEMES RELATED TO HYDROGEN

Hydrogen has become increasingly important in French and European energy projections. To optimise preparations to integrate this low-carbon molecule into gas infrastructure, French gas infrastructure operators have formed an inter-operator working group to consult on a common R&D&I strategy. This working group, comprising Elengy, GRDF, GRTgaz, Régaz, R-GDS, Storengy and Teréga, also makes it possible to pool/share certain work, particularly the current consideration regarding the protocol for converting existing infrastructure to H<sub>2</sub>, which could be the subject of a common guide to be validated by the authorities. Some projects are the subject of cooperation and co-financing to develop joint specifications and bids, while others are judiciously allocated before exchanging conclusions.



Hydrogen pressure chamber with tensile specimen.

## 2 - Preparing for the injection of blended hydrogen into storage facilities and ensuring the safety of the process

### THE AIM



R&I is conducting various projects to characterise the potential impacts of H<sub>2</sub> on Teréga's storage activities, from surface infrastructure (wells, processes, etc.) to geological reservoirs (geochemical and biological interactions with subsoil components or the aquifer). These compatibility studies will ultimately make it possible to determine the areas suitable for injecting H<sub>2</sub>, as well as the most suitable pressure and blending rates.

#### The approach

- Pressurised aquifer storage conditions are reproduced in the laboratory to assess the effects of the addition of H<sub>2</sub> at different concentrations on the geological reservoir and subsoil micro-organisms (RINGS-1 project with the UPPA and Storengy).
- The mechanical behaviour of well steels is assessed in an H<sub>2</sub> atmosphere (dry and wet), at ambient temperature and with impurities (TrOPHY project in collaboration with Storengy, IFPEN and the French Corrosion Institute).

#### Benefits

- Preparation for the injection of H<sub>2</sub> into the storage facilities while guaranteeing their integrity and performance.
- Anticipation of potential operational constraints.

#### Progress to date

- Finalisation of the RINGS-1 experiments: simulation of the impact of H<sub>2</sub> under Storengy storage conditions.
- Integration of SNAM (Italy) and ENAGAS (Spain) into the RINGS project for the sharing of results.
- Launch of the TrOPHY collaboration for a period of three years.

#### Future developments

- Interpretation of RINGS-1 experiments and preparation of subsequent experiments with the launch of a new thesis (RINGS-2).
- TrOPHY experimental testing and sharing of results with other operators.
- Identification of the equipment installed on the wells and study of their compatibility in collaboration with the various suppliers.

### METHANOGENESIS IN STORAGE FACILITIES?

In deep aquifers used to store gas, CO<sub>2</sub> can be found naturally in water and carbonated minerals, as well as in natural gas, which contains around 1% CO<sub>2</sub>.

It is therefore highly probable that micro-organisms present in the subsurface have the ability to consume H<sub>2</sub> and CO<sub>2</sub> as sources of energy and carbon and transform them into CH<sub>4</sub>. This is called methanogenesis. Teréga wants to improve its understanding of these mechanisms and quantify them in order to assess the changes induced by this type of bacteria on the properties of the gas returned to the gas shippers (modification of the calorific value or composition of the gas) but also on the performance of the storage (evolution of the bottom-hole pressure).

A pilot laboratory will be built and financed jointly with the UPPA to conduct these experiments.

## HYDROGEN ROADMAP AND AREAS OF EXPERTISE



STORAGE AND WELLS	STORAGE INFRASTRUCTURE	PIPELINES AND METALLURGY	COMPRESSION	GAS EQUIPMENT	EI2A*	END USERS
<ul style="list-style-type: none"> <li>• Metallurgy</li> <li>• Reservoirs</li> </ul>	<ul style="list-style-type: none"> <li>• Metallurgy</li> <li>• Processes</li> <li>• Design of facilities</li> </ul>	<ul style="list-style-type: none"> <li>• New networks and conversion protocols</li> <li>• Steel, welds and coatings</li> <li>• Welding under load</li> <li>• H<sub>2</sub> mapping</li> <li>• Effect areas</li> </ul>	<ul style="list-style-type: none"> <li>• Compressor compatibility and design</li> </ul>	<ul style="list-style-type: none"> <li>• Metallurgy</li> <li>• Sealing capacity and performance</li> </ul>	<ul style="list-style-type: none"> <li>• ATEX</li> <li>• Compatibility and calibration (transactional analysers, instrumentation, metering chain, F&amp;G detection, odourisation, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>• Downstream network compatibility</li> <li>• Sensitivity of industrial customers</li> <li>• Network capabilities</li> </ul>

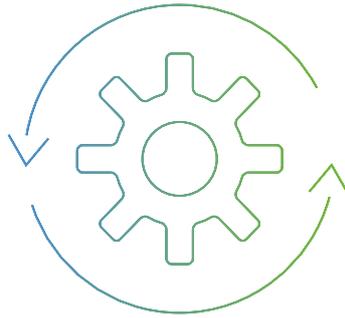
\* EI2A: electrical, instrument, automation, analysis.

## MULTI-ENERGY DEMONSTRATORS

Accelerating  
the energy transition  
means preparing  
for the future... today

**Jupiter 1000:**  
Teréga's regulated R&I CAPEX budget:  
€2.2m of which €0.2m in 2020

**Impulse 2025:** Teréga's regulated  
R&I CAPEX budget for phase 1:  
€0.3m of which €0.2m in 2020-2021



Since Teréga is committed to accelerating the energy transition, R&I is naturally interested in network **integration and multi-energy Smart Grids**. To improve the energy efficiency of regions, the various energy networks (electricity, natural gas, heat, cold and/or water) can no longer be considered independently. Teréga firmly believes that gas networks have a central role to play in balancing energy demand and, along with GRTgaz, has been involved since 2014 in developing the first French Power-to-Gas demonstrator, Jupiter 1000. The company went a step further in 2019 by launching the first phase of IMPULSE 2025, its large-scale smart multi-energy systems project.

***“By allowing the mass storage of electricity in the form of gas, Power-to-Gas represents a real opportunity for the development of renewable energies.”***



Mathieu Russac

Head of the Studies and Projects Department and JUPITER 1000 Project Manager for Teréga

***“The gas grid offers the possibility of linking the different energies and choosing the right energy for the right use at the right time. Multi-energy is a new approach required for the energy transition.”***

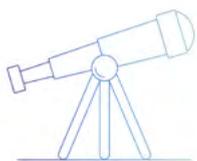


Antoine Simonnet

Multi-Energy Project Manager,  
IMPULSE 2025 Project Manager

# ▷ R&I projects that prepare the way for the future of gas

## 1 - Making an active contribution to Jupiter 1000, France's first Power-to-Gas Demonstrator



### THE AIM



This project underlines the ambition of Teréga and several of its partners, including GRTgaz, to demonstrate the ability of gas infrastructures to balance and underpin the electricity grids by leveraging Power-to-Gas technology.

The Jupiter 1000 project is designed to study the conversion of surplus renewable electricity first into green hydrogen via electrolysis of water and then into methane syngas by combining it with CO<sub>2</sub> captured from industrial flue gases.

This project highlights the complementarity between the gas and electricity grids by combining different technological building blocks (CO<sub>2</sub> capture, several electrolysis technologies and methanation).

### The approach

- Acquisition of skills across the full range of technical and operational issues related to Power-to-Gas.
- Tests will be conducted to validate technologies for injecting hydrogen into the network, producing and injecting methane syngas, and capturing and recovering CO<sub>2</sub>.
- Studying the viability of the Power-to-Gas financial model, its regulatory context and smart management of the entire system.

### Benefits

- Maximised integration of renewable energies and recovery of surplus electricity for re-use.
- Guaranteed security, quality and continuity of supply of new energies.
- Early-stage readiness for requests from future customers.

### Progress to date

- H<sub>2</sub> injection tests in various configurations.
- Installation of the methanation unit.
- First testing of sending instructions remotely.

### Future developments

- Finalisation of the CO<sub>2</sub> capture block, construction of the CO<sub>2</sub> pipeline and launch of methanation testing.
- Commissioning of the complete facility, remote control testing and characterisation of the economic optimum.



Electrolyser.

## EARLY TAKE-AWAYS

Following commissioning of the technological blocks for hydrogen production, blending and injection into the gas network, the first tests have been launched. This has provided initial data on the operation and performance of the alkaline electrolyser. This data can then be compared to data concerning PEM technology and be incorporated into modelling of the smart management of hydrogen production.

Initial exploratory work to identify and remove technical obstacles linked to the injection of H<sub>2</sub> has not so far demonstrated any impact on industrial uses downstream of the demonstrator for low concentrations of H<sub>2</sub> in natural gas (less than 2% vol.). The environmental study conducted in parallel also specified the benefits of Power-to-Gas in terms of energy and greenhouse gas balance.

Project supported by:



Project partners:



## 2 - Rolling out a smart multi-energy system: IMPULSE 2025 (innovating and mobilising to unify energy systems)

### THE AIM



Teréga's intention for this project is to roll out a smart multi-energy system to optimise the energy consumption of an industrial platform in real time by facilitating exchanges between the various players via the grids. This involves making the most of all energies and using the best one for each use, while maximising the integration of local renewable energies. IMPULSE 2025 is an R&I project carried out in partnership with the Ecole Polytechnique Fédérale de Lausanne (EPFL), an international leader in multi-objective optimisation, and the UPPA, recognised for its advanced expertise in thermal and dynamic process simulation.

### The approach

- During Phase 1 of the project (2019 to 2022) an optimisation and modelling tool is developed to identify the optimal configurations of a multi-energy system according to the targeted performance objectives.
- Many technological blocks are being studied and modelled (Power-to-Gas, Heat-to-Power, cogeneration, etc.). In parallel, a digital solution is being developed to provide real-time multi-energy system optimisation and control.

### Benefits

- Increased skills in the design, operation and management of a multi-energy system.
- Identification of the best technological blocks for grid integration.
- Identification of the role to be played in the multi-energy ecosystem and the future role of energy grids.
- Development of new sectors.
- Achieving carbon-free industrial platforms and enhancing their attractiveness.

### Progress to date

- Continuation of the joint work with the EPFL and the UPPA: incorporation of new technological blocks into static technical models, increased skills in simulation software and system optimisation.
- First dynamic modelling studies.

### Future developments

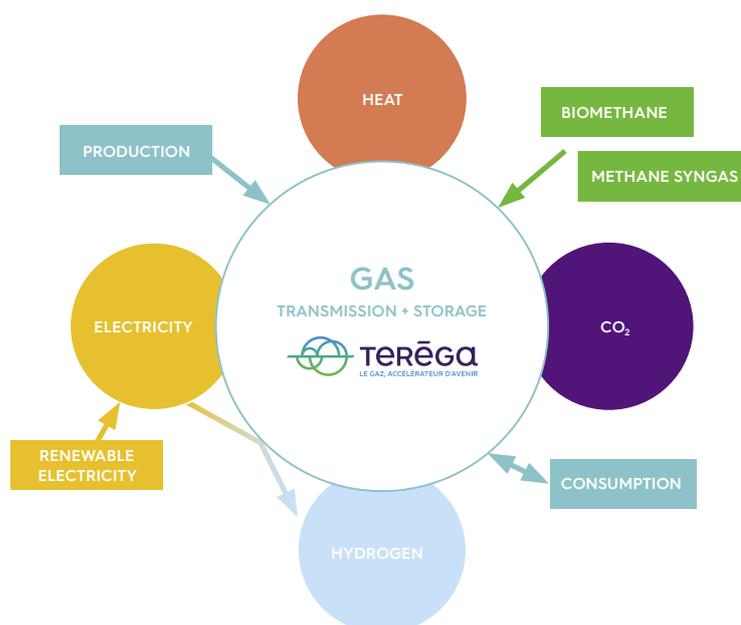
- Finalisation of phase 1 and use of the tools developed to optimise an industrial ecosystem defined as a pilot case.
- Preparation of phase 2 of the project, validation of the demonstration site and application of the IMPULSE 2025 methodology in an operational environment.



### NEXT STEP: THE DEMONSTRATOR!

Phase 2 of IMPULSE 2025 will involve the construction of a demonstrator to prove the operational feasibility of the concept of multi-energy grids and confirm the projected gains. The demonstrator will also incorporate all the digital infrastructure necessary to offer an optimal and smart system management solution. Various partners, particularly industrial companies and equipment manufacturers, will contribute to this phase, which will allow deployment of the various technological blocks identified to optimise the system. Subsequently, this demonstrator will also act as a test platform for roll-out of immature technologies that require testing on a well-defined scope.

### TEREGA INFRASTRUCTURE AT THE HEART OF ENERGY GRIDS



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# GLOSSARY



## **ATEXisation**

Certification of equipment, systems or components to make them compliant with European Directives for controlling explosive atmospheres (ATEX).

## **Cathodic protection**

“Active protection” technique against corrosion. It is achieved by applying voltage to the metal surface of the pipe to decrease its corrosion potential to a sufficiently low and acceptable level at which the metal’s corrosion rate is significantly reduced.

## **Corrosion**

Electrochemical process that deteriorates steel pipes.

## **Duct**

Steel or concrete sheath protecting underground pipelines from the various mechanical stresses generated by the external environment at certain points in the network (railways, motorways and rivers).

## **Easement strips**

Strips of land six to 10 metres wide centred along the axis of transport pipelines. They are regularly maintained and no construction or planting over 2.7 metres high is permitted.

## **Electrolysis**

The process used to convert electrical energy into chemical energy. Electrolysis of water is used to produce hydrogen.

## **Electrolytic hydrogenation**

Process occurring in a high pressure, high temperature electrolyser that directly, almost instantaneously, transforms hydrogen produced in-situ and CO<sub>2</sub> into various chemicals (including methane).

## **Environmental offsetting**

Set of environmental actions designed to counteract the damage caused by a project which cannot be avoided or reduced.

## **Geochemical tools**

Methods for determining, analysing and quantifying chemical compounds present in rocks, minerals, waters and terrestrial gases. It is a method based on a combination of geological and chemical expertise.

## **GESIP guide**

Professional methodological guide published by the GESIP (*Groupe d’Étude de Sécurité des Industries Pétrolières et Chimiques*) used by Teréga for the construction, monitoring and maintenance of its pipeline network.

## **Hydrothermal gasification**

Thermochemical process at high pressure (210 to 350 bar) and high temperature (360 to 700°C) which converts liquid organic waste into syngas. This process can be used to treat methanisation digestates.

## **Icephobic coating**

Coating that reduces the adhesion of ice to a surface.

## **Machine learning**

A technology based on artificial intelligence that enables computers to learn automatically and make statistical predictions from a given set of data.

## **Magnetic tomography**

An inspection technology using a magnetic signal from the surface to detect defects on underground pipelines.

## **Methanation**

A biological or catalytic industrial process in which carbon dioxide or carbon monoxide reacts with hydrogen to produce water and methane. This type of methane is referred to as methane syngas.

## **Predictive maintenance**

Predictive maintenance is based on the forecasting of breakdowns and failures to predict the condition of a device or item of equipment before it fails.

## **Pressure-reduction station**

Equipment whose function is to lower the pressure of the gas transported by the transport network to pressure levels that can be used by customers (public distribution grid, industry).

## **Power-to-Gas**

An industrial process in which surplus electricity generated from renewable energy sources is converted into hydrogen by electrolysis. This hydrogen can either be injected directly into the natural gas grid as blended gas or used as it is, or converted by

methanation into methane syngas by combining it with carbon dioxide captured elsewhere.

### **Proof of Concept (POC)**

Method for rapidly assessing the potential and feasibility of an idea, tool or product under real-world conditions.

### **Pyro-gasification**

Thermochemical process involving heating waste (dry biomass) to a very high temperature (from 800 to 1,500°C), in the absence of oxygen, in order to produce syngas.

### **Radar satellite imagery**

Imaging technology on board a satellite that uses the microwave spectrum. Compared with optical satellite imagery, this technique can be used in any weather conditions (low sensitivity to clouds) and at any time of day or night.

### **Resistance test**

Characterisation of a material's fracture properties when a notch is present. This corresponds to the amount of energy a material can absorb before breaking.

### **Seal**

Compressor component providing a dynamic layer between the rotating parts (rotating shaft) and the equipment's pressure vessel.

### **Stray currents**

Electrical flows caused by electrified railway tracks near a pipeline. Pipelines exposed to stray currents may be subject to a significant acceleration in corrosion phenomena.

### **THT**

TetraHydroThiophene, a compound used as an odorant for natural gas.

### **Trace compounds**

Compounds that are present in gas in very low concentrations, but which nevertheless pose potential risks to Teréga operations.

### **TSOAs**

Special lead-throughs in structures or in the open air (*Traversées Spéciales sur Ouvrages ou à l'Air libre*): Non-buried section of pipe (whether protected by a duct or not) constituting special points within the meaning of the hazard study (pipe affixed to a civil engineering structure, self-supporting, in a gutter, in a tunnel, etc.).

### **Undeclared Third-Party Work**

Work carried out by third parties near pipes which has not been the subject of a Regulatory Declaration of Planned Work (DT- *Déclarations réglementaires de projet de Travaux*) or a Declaration of Intent to Begin Work (DICT - *Déclaration d'Intention de Commencement de Travaux*).

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