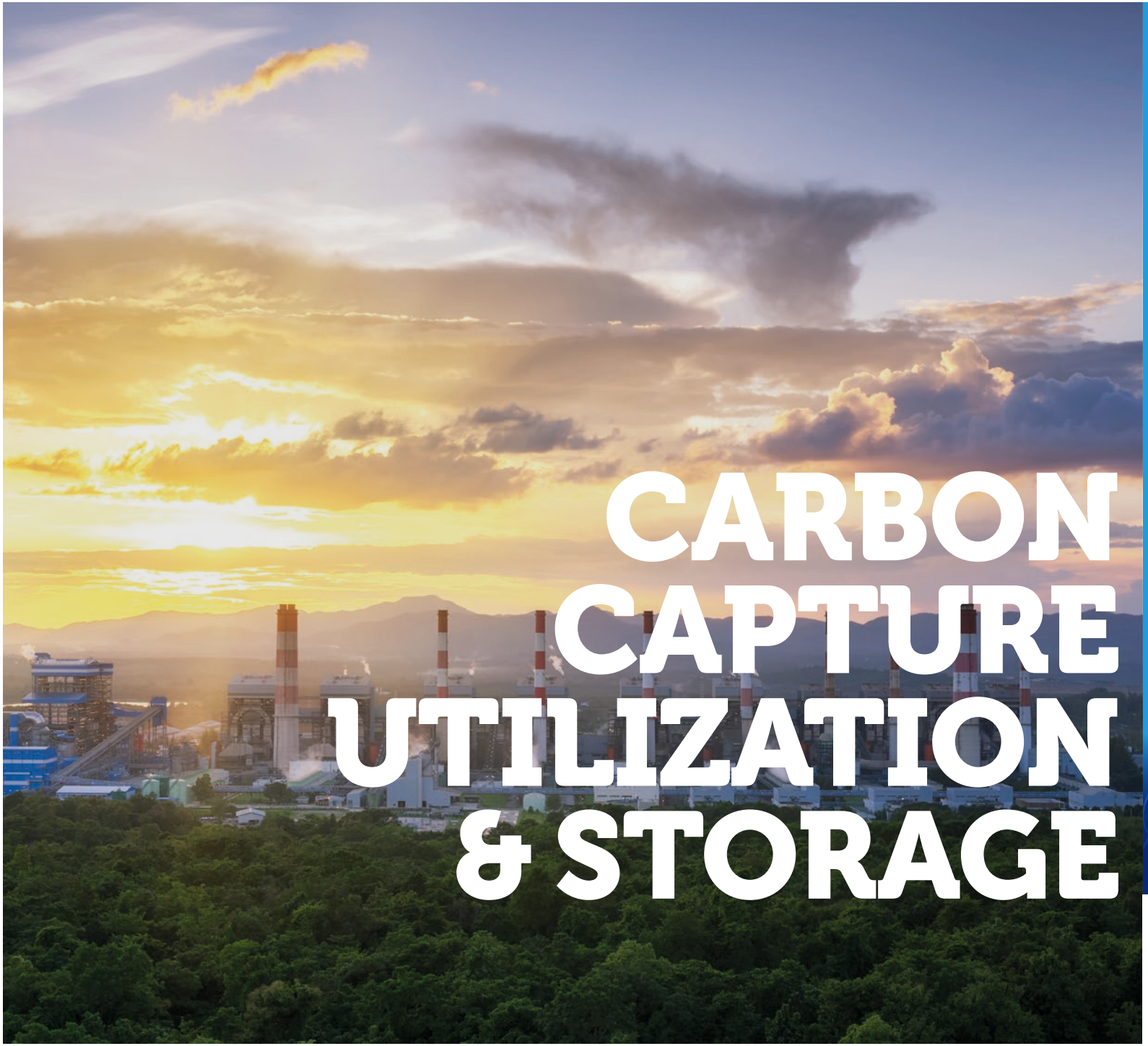

CARBON CAPTURE UTILIZATION & STORAGE

SOLUTIONS PAPER

BY LEILA FARAMARZI

CCUS Director

About Leila Faramarzi

Leila Faramarzi joined Vallourec's Energy Transition Department in 2020. As CCUS Director, she heads Vallourec's strategy in products, market and business development for CCUS. She holds a PhD in Carbon Capture from the Technical University of Denmark (DTU). Leila has 15 years of international experience in CCUS including her most recent experience at Equinor (formerly Statoil) in Norway.

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CCUS: AN INTEGRAL COMPONENT OF THE ENERGY TRANSITION

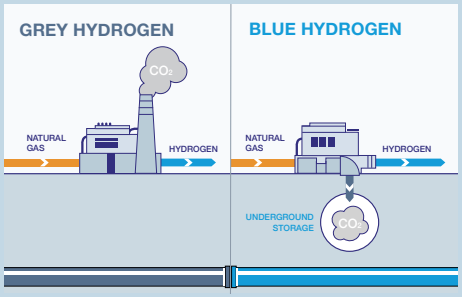
Carbon capture, utilization, and storage (CCUS) technologies are essential to deliver clean industrial growth and to achieve net-zero ambitions in accordance with global climate goals.

There is international consensus that CCUS will play a central role in new energy pathways – notably in the production of blue hydrogen. CCUS is also the **only existing option** for deep decarbonization of key sectors of the economy such as steel and cement manufacturing where carbon dioxide (CO_2) is not only produced via heating processes but also is a by-product of a chemical conversion processes. As such, CCUS is expected to account for **9%** of the cumulative emissions reduction between now and 2050[1].

Recently, CCUS has started to gain momentum as a result of new investment plans including the European Green Deal, tax credits such as the 45Q measures in the US and other reinforced international climate pledges. To play an effective part in decarbonizing economies, CCUS will require continued policy support for deployment at scale. Major cost reductions are expected as the number of commercial projects increases, thanks to both **economies of scale** and **knowledge gained from experience**.

SAFE STORAGE

As an example, power plants fueled by coal and gas still generate two-thirds of all electrical energy[2]. Retrofitting them with carbon capture technology can reduce emissions – perhaps by as much as **80-90%**[3]. To this end, the captured CO_2 will be stored permanently in dedicated geological formations such as saline aquifers or depleted oil and gas reservoirs. This technology, however, remains an emerging application and requires a global infrastructure leveraging the return of experience from the oil and gas industry to become demonstrated and practicable at scale.

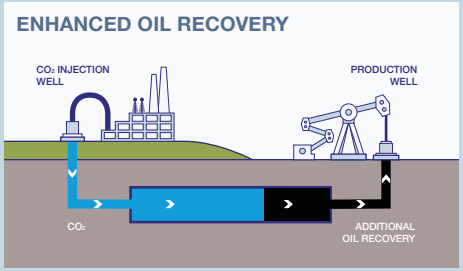


EOR, A PROVEN INDUSTRY PRACTICE

During CO_2 Enhanced Oil Recovery (EOR), CO_2 is injected into mature reservoirs to force oil towards production wells. Currently, a majority of the legacy CO_2 EOR projects inject CO_2 drawn from naturally occurring underground deposits, and some portion of the injected CO_2 returns to the surface with the produced oil and might be emitted into the atmosphere.

Companies using EOR techniques are working on injection of CO_2 captured from industrial sources as well as ways of ensuring that the resurfaced CO_2 is recovered for reuse in another round of oil extraction. This would result in decarbonation of industries.

For this to become an everyday reality, CCUS requires investment in capital-intensive long-lived capture assets along with safe transport pipelines and injection infrastructure.



HOW VALLOUREC CAN HELP

Vallourec is an end-to-end supplier of high-performance tubular solutions resistant to CO_2 environments, accompanied by services adapted to CCUS activities. We are uniquely positioned to help the CCUS industry overcome its specific challenges and deploy **safe and sustainable infrastructures** worldwide.

OVERCOMING CHALLENGES THROUGH OPTIMUM MATERIAL SELECTION

Ensuring the integrity of the entire CO_2 value chain – from point of capture all the way to storage and utilization – is of paramount importance to guarantee safe and cost-efficient deployment of projects.

MAKING THE RIGHT CHOICES

Companies in the CCUS sector need to be very careful when it comes to **selecting materials** for transporting and storing captured carbon. They must be vigilant in terms of product performance, quality, efficiency, reliability and suitability for the intended purpose. Special attention must also be paid to choosing materials that ensure **long lifecycle** for the new energy systems and hence enhance their sustainability. Optimum material selection comes from thorough knowledge of products available for transport lines and wells along with their properties, together with in-depth understanding of the specific challenges of each CCUS project.

Vallourec experts can support clients in choosing the right product for their project by taking into account factors such as the presence of water or impurities such as hydrogen sulfide, NOx, SOx or Oxygen that comes from industrial sources of CO_2, and whether the pipe is above or below packer. In addition to selecting products fit for purpose, Vallourec can help companies balance risk against costs in their material selection by recommending the "good enough" materials, ensuring projects are as cost-effective as possible without compromising safety and performance.

There are two major physical challenges currently facing the CCUS value chain : **preventing corrosion** and **managing temperature** drops to guarantee asset integrity. Both can be overcome through the selection and application of specialized products.

KEEPING CORROSION AT BAY

It is crucial that companies storing and transporting captured carbon pay careful attention to the choice of pipelines used, ensuring they resist corrosion. Pipe choice must also take into account the CO_2 stream composition to be transported or injected based on, the method of carbon capture used and the possible presence of impurities, as well as the environment and reservoir in which the CO_2 is to be stored. Durable, pressure- and corrosion-resistant tubular solutions are crucial to building a safe carbon reservoir.

Vallourec's corrosion experts have drawn on their decades of experience with sour service conditions where the risk of corrosion is extremely high to develop a suite of products that covers every need. We provide several types of **casing and tubing**, including conductor casing, surface casing, intermediate casing, production casing, and production and injection tubing. Our comprehensive portfolio of seamless pipes from carbon steel to CRA (Corrosion Resistant Alloy) are highly corrosion-resistant and available in a **range of dimensions**. Expertise in threading allows Vallourec to deliver durable products and long-lasting casing and tubing that can withstand harsh environments and guarantee firm sealing.

ASSET INTEGRITY AT STAKE IN CO_2 TRANSPORTATION AND INJECTION

Asset integrity is key to the long-term success of CCUS projects, both for transportation and for injection.

To ensure the integrity of pipelines that transport captured carbon, industry players must make many important choices that impact their pipeline needs. One of these choices includes the option to deeply purify the CO_2 stream before transporting it which can potentially save material costs downstream. Without ensuring very pure CO_2 streams, more advanced materials are needed for transportation and storage of CO_2. Ideally, the cost of the CCUS value chain has to be optimized globally.

Vallourec's experts have developed secure, leak-proof transportation pipelines that can withstand a range of different pressure and temperature levels – key to the success of CCUS. These high-standard pipelines address extreme environments and provide improved tube performance, enhanced weldability, and better resistance to corrosion. This makes them ideally suited to CCUS transportation applications.

Transport and injection of CO_2 in dense phase (liquid or supercritical) presents its own set of challenges, one of which is temperature drops in case of a sudden depressurization of the fluid. Cyclic thermal shocks as well as extreme cooling can cause pipe **cracking, break or burst** if they are not sufficiently robust. Therefore, material toughness is another important element.

Vallourec offers a range of seamless tubular products to help operators address these challenges and **avoid leakage or blow-out**. Our expertise in materials selection enables us to understand our clients' requirements and provide the right grades with the proper toughness characteristics to meet project needs.

And with tight connections essential when injecting CO_2 into depleted reservoirs and saline formations, our premium VAM® connections are designed to provide gas-tight storage. These include our best-selling VAM® TOP as well as our latest VAM® 21 connection, which combines the highest proven technical performance with outstanding metal to metal sealability and extreme compression resistance. The connection has been extensively tested using the **strictest industry protocols**, and is trusted and used by operators worldwide.

THE RIGHT SERVICES TO OPTIMIZE PRODUCT PERFORMANCE

In addition to its high-performance products, Vallourec has a suite of services to support client projects of all types and sizes.

CONSTANT VIGILANCE TO ENSURE COMPLIANCE

The goal of CCUS is to reduce carbon emissions from industry operations. So it stands to reason that, as the industry evolves towards standards, qualification and certification, regulations must be extremely strict. Leakage from underground CO_2 wells, for example, will be monitored as a means of protecting personnel and limiting environmental damage. In response to this challenge, we have developed a range of digital, traceability and tubular management services **to optimize pipe operations**. Key to this offer is our innovative annulus monitoring solution.

MONITORING PIPES WITH REAL-TIME DATA

One of these advanced technologies is Vallourec's **Intelligent Pipe solution**, designed to reinforce, characterize, and optimize wells.

The Intelligent Pipe solution is embedded with advanced sensors to monitor, among others, pressure and temperature. They provide **real-time downhole measurements** between casing and tubing in previously hard-to-access areas, checking for CO_2 leakage. By offering access to the formation beyond casings and capturing any geological movements, the Intelligent Pipe solution allows users to accurately characterize the well environment in question. Operators can **monitor abnormalities** and anomalous behavior and **detect leaks** in real time, enabling them to react before the injection well's integrity is compromised.

Monitoring solutions like Intelligent Pipe enhance asset integrity and ensure compliance with stringent CCUS regulations that will only get stricter and more uniformly enforced as the industry develops. They **optimize production efficiency** and improve resource management throughout the product lifecycle. Plus, in the bigger picture, monitoring solutions that generate accurate and timely data to prevent harmful leaks make a significant contribution to protecting the planet and its people.

MAKING THE MOST OF WHAT YOU'VE GOT

To ensure customers reap the full benefits of its products, Vallourec offers a wide **variety of services** that help optimize efficiency and performance.

Serimax: maximizing welding performance
Serimax is Vallourec's full-service welding subsidiary offering integrated welding solutions for operations on land and at sea in the most extreme conditions and challenging environments.

Their specialized welding services come into their own in CCUS projects to ensure the safe transfer of CO_2 from emission sources to storage sites. Serimax provides fully integrated welding and fabrication onsite. By welding tubes together every 12-13 meters, we can produce pipelines over 150 km long. The result is tightly sealed tubular solutions.

OPTIMIZING CONNECTIONS WITH VAM® FIELD SERVICES

Tight connections are crucial to building a safe carbon reservoir. Vallourec's international network of VAM® Field Service technicians help CCUS customers verify and deploy OCTG connections at their injection sites.

As well as ensuring smooth running, expert support enables users to avoid non-productive downtime and boost rig operations efficiencies, thus reducing costs.

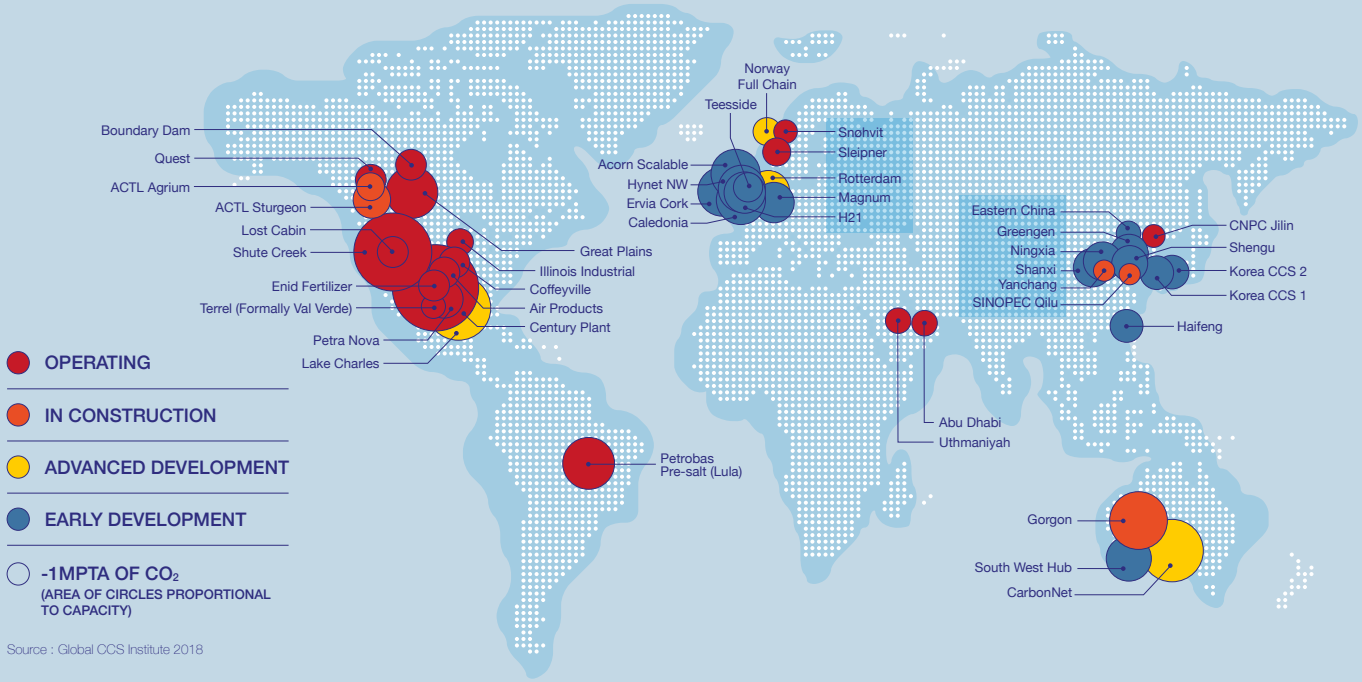
THE POWER OF DIGITAL, VALLOUREC'S SMARTENGO SOLUTIONS

The digital solutions available within the Vallourec.smart offer have myriad advantages for CCUS customers, including **time and costs savings, greater operational efficiency, and higher productivity**.

Building on unique pipe identification, traceability and user-friendly applications, these Smartengo solutions help CCUS customers optimize operations and improve the management of assets. From Smartengo Best Fit, a digital solution for traceability, fit-up and pipeline construction, to Smartengo e-commerce, an online e-commerce plateform for OCTG products and more, Vallourec's digital service offer leverages the latest technologies to support operational performance and, ultimately, reduce total cost of ownership – an important factor in CCUS projects, where upfront costs are currently high.

VALLOUREC COLLABORATES WITH INDUSTRY PLAYERS TO ADVANCE CCUS

CCUS is a key short-term innovation for industries looking to reduce CO_2 emissions and limit climate change. Vallourec is supporting the environmental aims of CCUS players by providing practical responses to industry needs along the whole value chain.



Source : Global CCS Institute 2018

EARLY-STAGE RESEARCH

With five advanced research centers around the world counting **430 researchers and technicians** among their staff, Vallourec is fully committed to driving progress in the CCUS sector. In 2020, we invested **€41 million** in R&D projects, including a large part for Energy Transition topics, and we have worked for many years to develop academic partnerships in Europe, the USA and Brazil.

Early engagement in the high-potential CCUS market is important to help burgeoning environmental technologies get off the ground. Vallourec has been involved in several Research & Development projects with **energy companies** as well as research and academic institutes, helping to close knowledge gaps.

As an example, we recently took part in **Joint Industry Projects** together with several energy companies to investigate metallic material degradation in CO_2 injection wells or to define the safe operation window of carbon steel pipelines in CO_2 transportation. Additionally, we have been part of other **multilateral research groups** looking into modelling of dense phase CO_2 release, material compatibility, corrosion and corrosion control, as well as impact of impurities.

WORKING WITH MAJOR PLAYERS ACROSS THE GLOBE

We are seizing opportunities to develop our CCUS support business around the globe, with particular emphasis in Europe as well as in North America. The North Sea is of particular interest, as European energy giants are all expanding their CCUS activities and Vallourec is committed to supporting their projects. **In collaboration with many major players**, Vallourec is working to provide technical support to qualify the right materials and connections for CCUS applications.

As the infrastructures for CCUS develop, we are innovating the required durable, corrosion-resistant, end-to-end tubular solutions capable of transporting and storing CO_2. Our products are backed up by **practical and digital services**, including the Smartengo suite, for enhanced traceability and tubular management.

IN THE FIELD

Vallourec has already had many opportunities to apply knowledge from research and development to real-life projects. Recent examples include providing onshore transport pipelines and OCTG products for technically complex CO_2 EOR projects with sour service conditions in the Middle East.

On the other side of the world, in South America, Vallourec provided tubular solutions for offshore CO_2 WAG (Water Alternating Gas) applications, using a wide range of metallic materials.

CONCLUSION

In the gradual transition to low-carbon energies, CCUS offers a real opportunity to reduce the carbon footprint of industrial operations.

Vallourec remains committed to supporting CCUS development as part of its engagement in a host of low-carbon initiatives. Building on our long experience and deep expertise in tubular solutions and associated services, we are ready to act as an end-to-end supplier that can help the industry develop safely and sustainably.

Vallourec's experts have an in-depth knowledge of the challenges involved in bringing CCUS technology to the fore on a large scale. As such, we are uniquely positioned to offer safe, efficient and high-performance solutions for low-carbon energy systems. With a worldwide presence, we can support CCUS projects of every type and size, no matter where **around the globe**.

[1] World Energy Outlook, 2019
[2] The Role of CCUS in Low Carbon Power Systems, 2020
[3] IPCC Special Report on Carbon Dioxide Capture and Storage, 2018

NEED MORE INFORMATION?

Information is avaible online on solutions.vallourec.com.

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SMART TUBULAR SOLUTIONS