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ADVANTAGE

POWERING INNOVATION THAT DRIVES HUMAN ADVANCEMENT

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Simulation Powers Energy and Sustainability

Ansys

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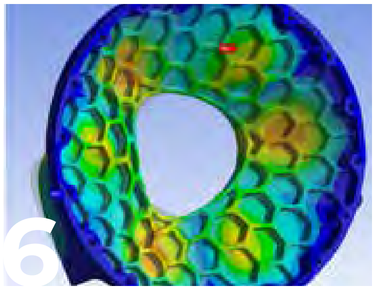

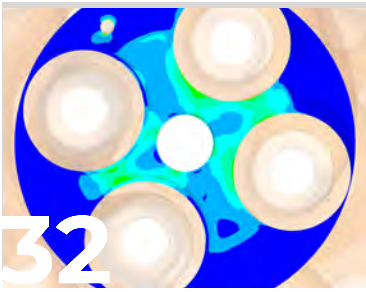

Focus on Energy and Sustainability

ADVANTAGE

Welcome to *Ansys Advantage*! We hope you enjoy this issue containing articles by Ansys customers, staff and partners.

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Powering Innovation That Drives Human Advancement

When visionary companies need to know how their world-changing ideas will perform, they close the gap between design and reality with Ansys simulation. For more than 50 years, Ansys software has enabled innovators across industries to push boundaries by using the predictive power of simulation. From sustainable transportation to advanced semiconductors, from satellite systems to life-saving medical devices, the next great leaps in human advancement will be powered by Ansys.

Ansys is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and engineer products limited only by imagination.

Using Digital Engineering to Solve the Energy Trilemma

By **Scott Parent**, VP and Field CTO, Energy, Aerospace, Semiconductor, and Industrial, Ansys

Today's global energy industry is faced with a trilemma, which is easily summarized by three statements:
1. We need securable, affordable, and scalable energy to serve our growing population.
2. That energy must be delivered, converted, and consumed more efficiently.
3. We need new, cleaner energy sources to support this growth and replace a large portion of the fossil fuels because their combustion is a major cause of greenhouse gas (GHG) emissions.

As usual, stating the problem is easier than solving it. Regarding point 1 above, while we have delivered electricity to about 1 billion more people in the past few decades, there remain about 1 billion people without access to electricity. So, we must scale up energy production and delivery while simultaneously trying to reduce our global carbon footprint.

Point 2 drives home the magnitude of the energy challenge that we face. Today, 60% to 67% of the energy that is sourced, converted, and consumed worldwide is wasted through inefficiencies.[1] Improving energy efficiency could provide more than 40% of the reductions in carbon pollution needed by 2040 to meet the terms of the Paris Agreement on climate change.[2]

Point 3 — developing cleaner sources of energy — may seem obvious, but that doesn't make it easy. Each new source has its own challenges.

Fortunately, digital engineering — the application of digital technologies to engineering, encompassing design, simulation, optimization, and operation of systems and processes over the life cycle of a product — is already making a big contribution to energy efficiency and sustainability. Its contribution will only increase with time.

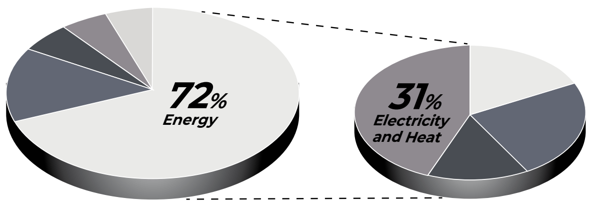
EFFICIENCY FROM START TO FINISH

To reduce our current energy consumption and our GHG emissions by about 40% in the short term — and the short term is probably all we have to slow the pace of climate change — the best plan is to improve energy efficiency in all products and processes.

Consider that 31% of the world's GHG footprint today comes from the conversion of fossil fuels into electricity and heat[3] and ~45% of that electricity is used in electric motors alone.[4] So, today's electric motors, before the massive electrification of the transport sector that will happen in the next decades, are already contributing about 15% of the total GHG produced by humans. Any efficiency increase in electric motors will directly reduce global GHG emissions by a few percent. That sounds small, but it would be a big win for the planet. One of our customers that produces water pumps has improved their product's efficiency by more than 80% over the last decade or so. They credit simulation at the component and integrated systems levels for the achievement of such remarkable results, which explains why they are No. 1 in this space.

Digital engineering is the main accelerator to achieve this efficiency. Ansys is committed to supporting our customers to achieve these goals:
- Adopting sustainability-by-design principles to make better product life cycle impact assessments from the start
- Accelerating the new energy transition by maturing low-carbon technologies

Global Manmade Greenhouse Gas Emissions



Globally, the primary sources of greenhouse gas emissions are electricity and heat (31%).[3]

SUSTAINABILITY BY DESIGN

Incorporating sustainability into the design process from its earliest phases is important because most of a product's cost and carbon footprint are determined during the development and design cycle. That's where the product's mass energy consumption is set in stone.

Critical decisions at this point include materials selection: the weight of a material can largely affect the energy efficiency, and the recyclability of a material can affect costs and sustainability. Simulation solutions like Ansys Granta MI, which contains a comprehensive library of material properties that can be easily imported into simulations, can help engineers choose the most energy efficient and cost-effective materials.

Lightweighting is another path to energy efficiency. Determining the optimal shape of a component using topological optimization in Ansys Mechanical can lead to nonintuitive shapes that reduce the weight of the component without sacrificing strength.

Think of it this way: If you have to extract, ship, manufacture, and deliver to market 30% less material, you've greatly improved the product's life cycle efficiency along the way, including end of life when there is 30% less material to recycle.

ACCELERATING THE NEW ENERGY TRANSITION

The advent of the internet of things (IoT) and 5G communications, with connectivity growing by orders of magnitude, is driving the energy sector through an extensive digital transformation that is a tailwind for energy transition. One aspect of that transformation that we should not forget is that many of these energy assets were installed and commissioned before the dawn of the digital age. Eventually, these older assets will have to undergo digital transformation through the addition of sensors, actuators, and communications devices so they can be an integrated part of the IoT. This transformation will be complex, but it will also be made possible by digital engineering. Creating a digital thread that links all assets — old and new — into a single system that can be monitored by digital twins to optimize efficiency, asset health, and full, real-time performance, is equally key to sustainability.

However, in the long term, and to meet 2050 net-zero targets and beyond, we will need to mature low-carbon solutions. Digital engineering, simulation, and the broader digital transformation of the energy sector will all be accelerators in the maturing and scaling of these net-zero targeted solutions.

In this issue of *Ansys Advantage*, we tell the success stories of some of our customers who are using digital engineering to help solve the energy trilemma. It is critical to the future of this planet that they succeed.

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AN INDUSTRY EXAMPLE: MATURING OFFSHORE WIND

The U.S. Department of Energy (DOE), through the National Renewable Energy Laboratory (NREL), has divided the problem of maturing offshore wind into four grand challenges that will require models and simulation to scale and solve some of the industry's major issues:

1) THE ATMOSPHERE: To improve wind turbine performance and reliability, researchers must increase characterization of air turbulence wakes (slower air movement downwind of a wind turbine) and local climates to understand their effects on energy generation.

2) THE WIND TURBINE: Increasing sizes and flexibility of wind turbines have surpassed modeling tools. To update these models, researchers need more large-scale experimental data to validate upgrades and develop mew simulation tools.

3) THE PLANT AND GRID: To optimize wind energy generation, further research must analyze complex airflow through wind farms. Hybrid power plant systems can contribute to the electric grid.

4) DATA HANDLING: Large amounts of global data have been gathered through research on wind energy. This data needs to be made accessible to the industry to efficiently support further research and development, along with standardization (digitalization) among stakeholders.

Sub-challenges include the simulation of site selection, wind farm layout, rotor dynamics, blade mechanics and noise, tower integrity, hydrodynamics, and mooring dynamics. Specific components such as the rotor shaft, nacelle structure, and generator must also be simulated and optimized.

Winds of Change

By Ansys Advantage Staff

Startup siWING is changing the way the world thinks about wind power, with its small turbines designed for private use. The company relies on engineering simulation to maximize power generation, while minimizing product size and weight to appeal to consumers. Its small, aesthetically pleasing designs are poised to make a big impact on the global energy industry.

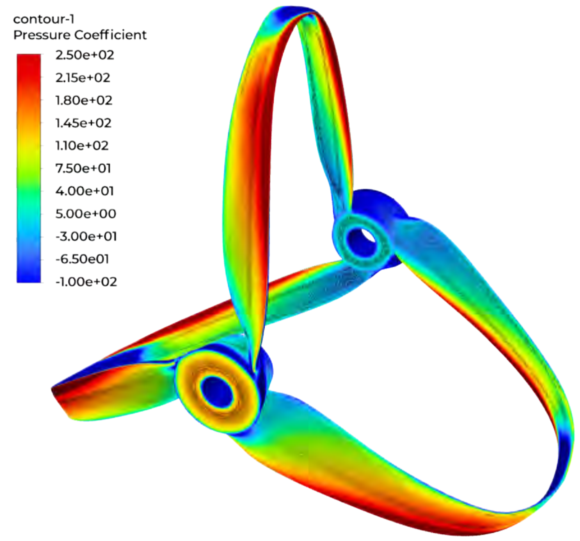
siWING hopes to make the sight of private wind turbines as commonplace as residential solar panels.

The sight of photovoltaic panels mounted on residential homes has become commonplace as consumers seek to increase their energy independence, control utility costs, and adopt more sustainable practices. An innovative startup company called siWING — shorthand for "smart, intelligent wings"— was founded with the goal of making private wind turbines just as common. Headquartered in Germany, siWING is quietly revolutionizing wind power as it prepares to launch its ROTOLUS product line this fall.

Ranging in size from 6 to 24 meters tall, ROTOLUS turbines are capable of producing more than 25,000 kWh of energy per year — which could provide power for about five homes. Even its smallest designs can generate over 2500 kWh, half of the average home's annual energy needs. It's a solution that makes sense from a cost and sustainability perspective. But, according to Dr. Paul Köster, Lead R&D Engineer at siWING, the company still needs to win the hearts and minds of customers.

"Our single biggest challenge has always been product innovation, because we're trying to change an entire category," notes Köster. "We believe there is a huge potential audience of private consumers, tradesmen, small and medium-sized companies, and even global corporations that want to equip their branches and subsidiaries with small wind turbines as a visible sign of the energy revolution.

"What all these customers have in common is that they want a reliable product that is absolutely safe to operate, easy and uncomplicated to set up, aesthetically pleasing to look at, runs silently, and delivers as much output as possible," Köster continues. "The only way siWING has been able to meet all those needs simultaneously is to completely reimagine the traditional wind turbine —



Rotor surface pressures as determined by Ansys finite element analysis

Exploded view of the generator for the siWING wind turbine

including its size, the shape of its blades, its aerodynamics, and other foundational characteristics."

Köster is confident that the ROTOLUS product line will deliver all these benefits — and he's led the application of innovative engineering tools and practices, including simulation, to verify every aspect of product performance leading up to the market launch.

SHAPING A NEW GENERATION OF WIND POWER

While large commercial wind turbines have a long history of usage and a set of design principles that are generally accepted, Köster and his team were starting from scratch in engineering their smaller turbines. One of the most distinctive features of siWING's turbines — their uniquely shaped blade design — was born of necessity.

"We couldn't simply downsize a commercial blade design because the shape simply won't work at such a small scale," Köster explains. "The blades would have to rotate very quickly and would emit a high level of noise. We had to arrive at our own optimal blade shape. Similarly, we had to completely redesign the mast and explore new materials to reduce vibration. Given the range of consumer needs, and the many forces acting on the product design, we knew from the beginning that we were undertaking a complex engineering task."

To accomplish the necessary analysis both quickly and accurately, siWING engineers relied on a suite of Ansys solutions, including Ansys Fluent, Ansys Mechanical, and Ansys SpaceClaim.

"Since our aim is to develop a product that's optimized in terms of its optical design, power efficiency, sustainability, and operational safety, both fluid dynamics and structural mechanics are critical — and the associated fluid–structure interactions are equally important," Köster says. "At siWING we don't focus on one special part of our wind turbine only. It needs to perform as a fully realized system.

"Ansys uniquely makes it possible and user-friendly at the same time to master the multiphysics tasks, which inevitably come together when developing complex systems such as wind turbines," continues Köster. "One great advantage is Ansys Workbench, which easily integrates the most diverse tasks and eliminates time-consuming, error-prone exports and imports. Workbench allows our engineers to easily connect all the different tools used during the development process in a clear manner, whether for a single part or for the whole turbine design. All calculations and simulations are seamlessly linked to the design — and

> ***"Ansys uniquely makes it possible and user-friendly at the same time to master the multiphysics tasks, which inevitably come together when developing complex systems such as wind turbines."***
>
> **— DR. PAUL KÖSTER,**
> Lead R&D Engineer at siWING

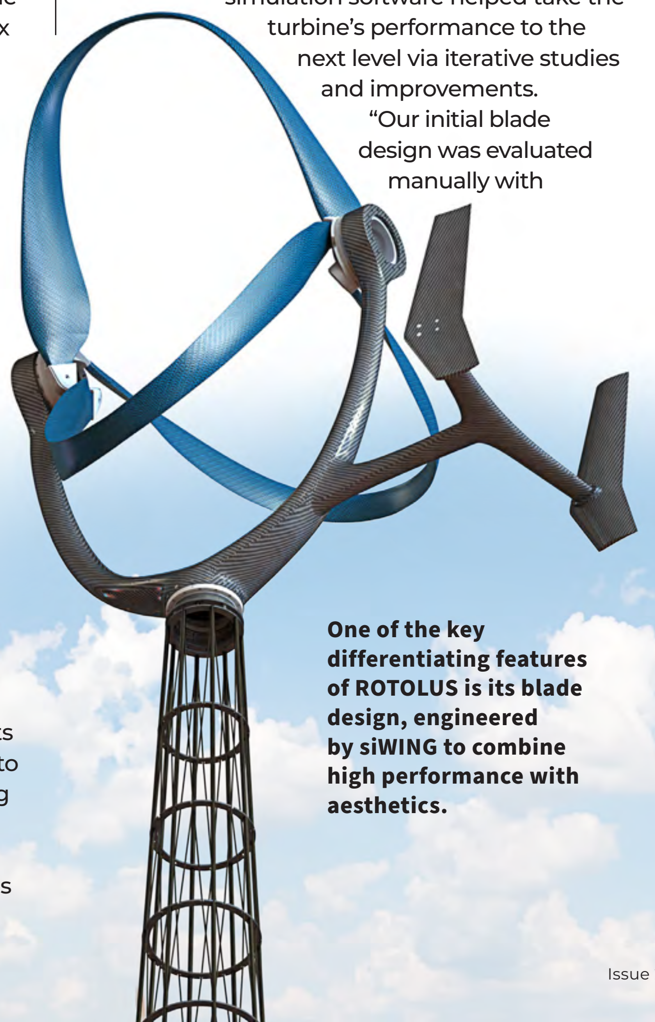
also dynamically integrated via the use of the geometry interface.

"The Ansys software ergonomics are on a much higher level compared to the programs we used before," he adds. "We can work much faster, more efficiently, and more precisely. It would not have been possible to solve all the required aerodynamic calculations and launch ROTOLUS into the marketplace as quickly if we were not using Ansys."

ACHIEVING FAST, ACCURATE OPTIMIZATION

As the siWING product development team worked to perfect the ROTOLUS design, Ansys simulation software helped take the turbine's performance to the next level via iterative studies and improvements.

"Our initial blade design was evaluated manually with



One of the key differentiating features of ROTOLUS is its blade design, engineered by siWING to combine high performance with aesthetics.

the blade element method and guided into a target corridor. This led to a total power coefficient of 0.41, which we also verified in elaborate experiments," notes Köster. "Then Ansys simulations helped us get detailed information for every section of the blade regarding the local flow conditions. Based on that analysis, we were able to improve and customize the blade — for example, by modifying local twist angles and cord lengths, as well as the overall blade length and shape. Ansys enabled us to achieve a power coefficient of 0.49, which is an excellent value."

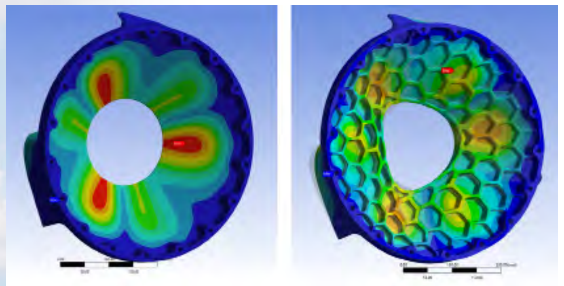
Another component optimized via Ansys simulation is the rotor hub that connects the blades to the main shaft and powers the generator through its rotation.

"The siWING team used Ansys software to optimize the topology of the hub for weight, strength, and stability," Köster explains. "We determined the exact wind loads in Fluent, then used Mechanical to design an appropriate hub structure to brave them. However, the hub not only had to withstand the physical forces of wind safely and reliably, but it also had to be as light as possible."

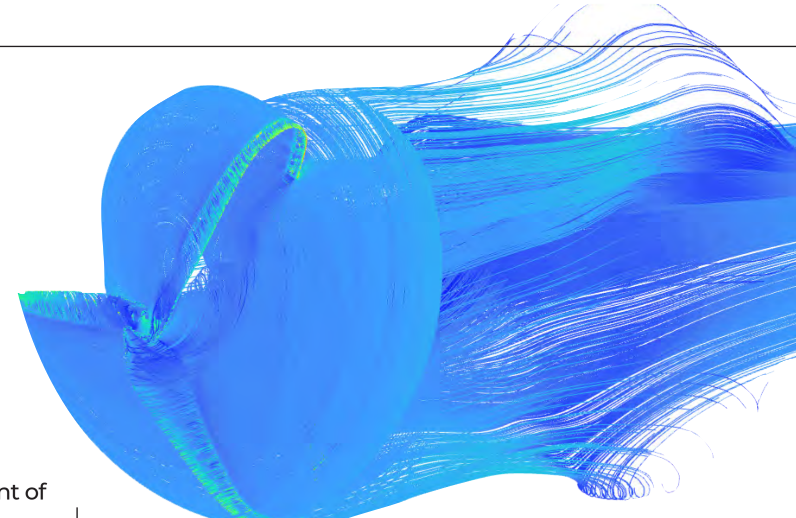
To achieve this, the team started with an easy-to-fabricate target design and tested it against the loads. In the next step, siWING engineers used topology optimization to identify areas with low material stresses, eliminated them, redesigned the model with SpaceClaim, and optimized it again.

"Ansys simulations allowed us to apply many design conditions simultaneously, including loads, which led us to a topology which provides optimized lightweight properties at consistent stability and strength," says Köster. "The weight of the hubs was reduced by around 45% as a direct result of our simulations."

In the final step, material was added to the hub design only at those points where it resulted in a significant manufacturing advantage. siWING could select the simplest casting process without compromising performance. "The ability to design for manufacturability is an important advantage of Ansys software," Köster points out.



Finite element analysis of the ROTULUS aluminum hub enabled a weight reduction of 45%.



Airflow through blades as simulated by Ansys Fluent

A POWERFUL PARTNERSHIP

Looking back, Köster acknowledges that his team was tackling an engineering challenge that seemed insurmountable.

"We needed to produce a completely new turbine design that is compact, slow-running, and quiet on the one hand," says Köster. "On the other hand, it had to be extremely powerful, with a very high coefficient of performance. But we also had to engineer ROTOLUS carefully from a design point of view. Its harmonious appearance is an essential differentiating factor."

Köster cites siWING's partnership with Ansys as a critical factor in overcoming this multifaceted engineering challenge. "Ansys is an important strategic partner for siWING," Köster emphasizes. "siWING bases its entire simulation strategy on Ansys. What siWING appreciates most about Ansys is its technical functionality, diversity, and quality, as well as its elite channel partner, INNEO Solutions, which has provided us with excellent support here in Germany."

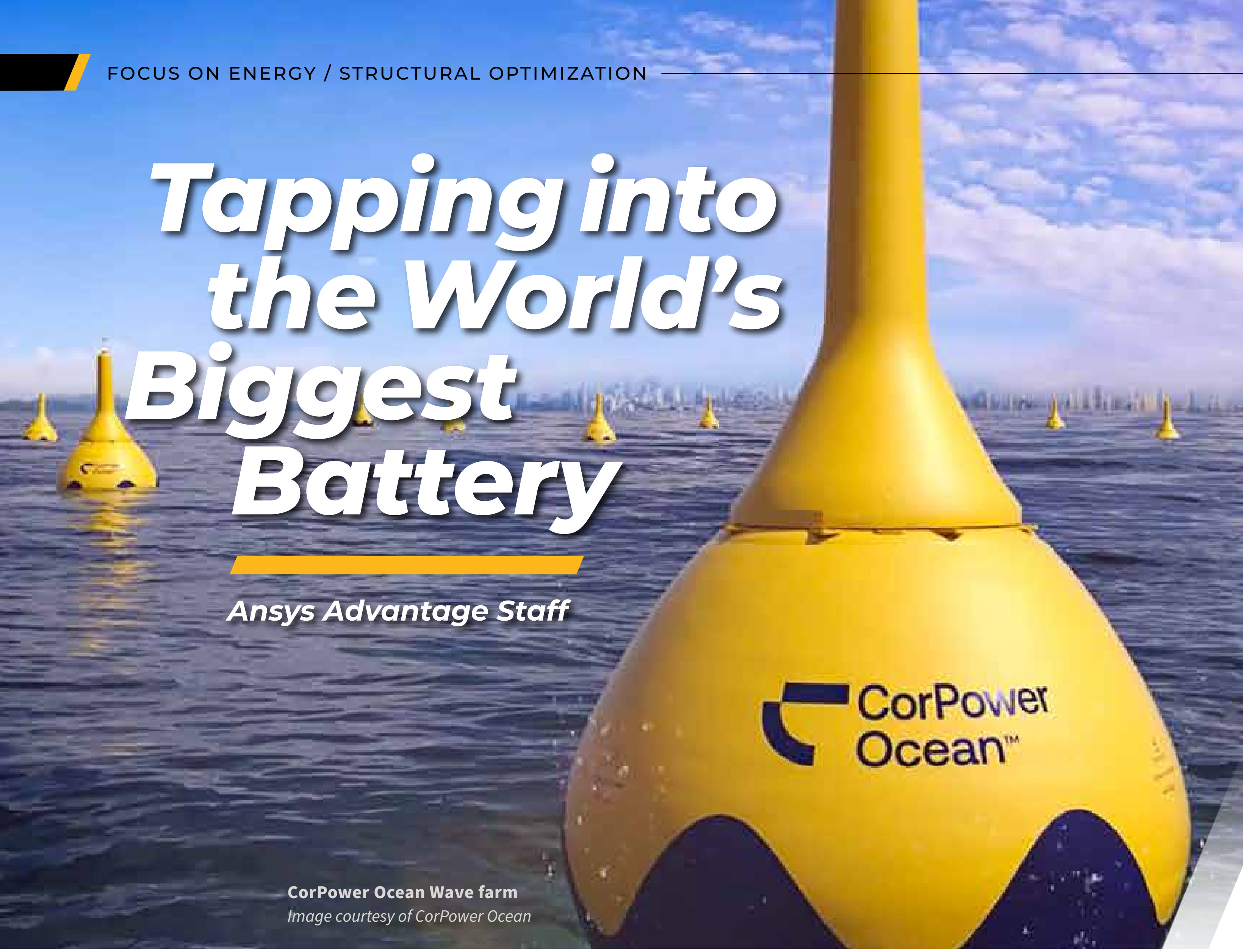
According to Köster, the upcoming ROTOLUS product launch wouldn't be possible without Ansys engineering simulation.

"Our comprehensive Ansys package enabled us to conduct the rigorous analysis that was required to verify our design, while saving valuable resources. We greatly reduced the need for time-consuming physical tests through intensive calculations, fluids studies, structural analyses, and the coupled variants of both," Köster concludes. "Thanks to Ansys, we're confident in the ability of ROTOLUS to meet consumers' expectations for safety, quiet performance, and a pleasing appearance — as well as maximum energy output."

As siWING prepares to change the residential energy category, a small, beautifully designed wind turbine may be coming soon to a backyard near you.

Tapping into the World's Biggest Battery

Ansys Advantage Staff



CorPower Ocean Wave farm
Image courtesy of CorPower Ocean

Think of the ocean as the world's biggest battery. That's what CorPower Ocean does. The Swedish firm has developed a wave energy technology that heaves with the movement of the ocean. Patented technologies inside the buoys transform the ocean's wave energy into clean, renewable electricity that can power hundreds of thousands of homes and businesses. And unlike wind or solar energy generation systems, CorPower Ocean's buoys don't stop generating electricity when the sun sets or the wind settles. The buoys ride the swell of the waves — a more reliable and predictable power source — day and night, helping to balance the grid with clean electricity.

Like any technology designed for use at sea, success depends upon the technology's ability to perform properly under variable and unforgiving conditions. Yet as in any young company with a big idea and a small budget, it's not possible (or even desirable) to build, haul out to sea, and test prototypes of every single technology or buoy design variant that the company's engineers might propose. How best to cost-effectively ensure that designs will survive and perform reliably in these conditions? CorPower Ocean's engineer's rely on simulation tools from Ansys.

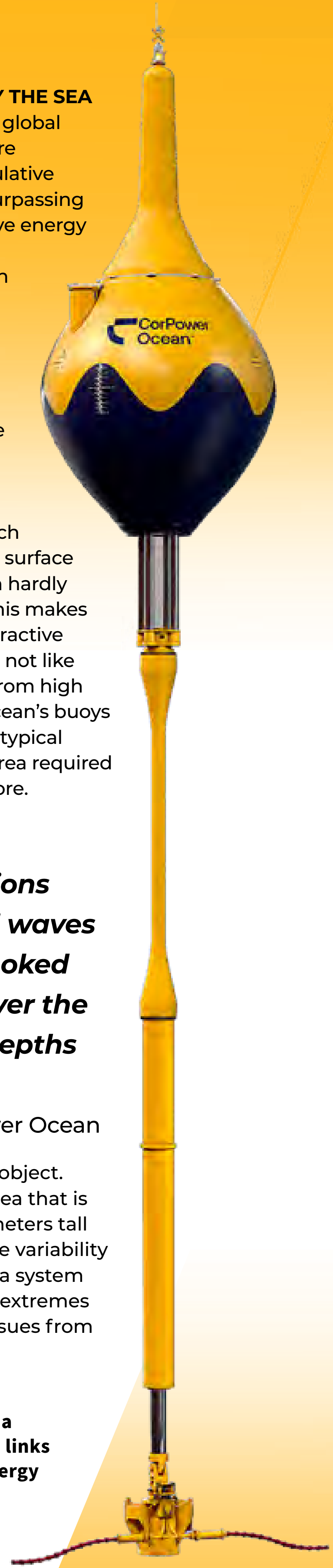
SIMULATING SURGES BY THE SEA

With an easily exploitable global potential of 500 GW, a figure comparable to today's cumulative hydro capacity — and even surpassing todays' nuclear capacity — wave energy stands out as one of the world's largest untapped sources of clean energy. CorPower Ocean's wave energy converters are designed to be tethered to the sea floor, and a CorPack cluster of buoys can produce 10 MW–20 MW of electrical energy. Multiple CorPack clusters can be linked — all sharing a common electrical transmission infrastructure — to deliver gigawatts of electricity.

At the same time, much of the body of each 19-meter buoy sits like an iceberg beneath the surface of the ocean. Even from a nearby coast, you can hardly see the slender tops of the tear-shaped buoys. This makes the CorPower Ocean wave system much more attractive to coastal communities. These communities might not like big wind turbines blocking their view of the ocean from high above the water. Indeed, a wave farm of CorPower Ocean's buoys configured to produce the same electrical output as a typical oceanic wind farm takes up only a third of the surface area required by such a wind farm and is virtually invisible from the shore.

> ***"We used simulation throughout the design phase. We ran all kinds of simulations involving storms of differing strengths and waves slamming against the hulls of a buoy. We looked at simulations where giant waves washed over the buoys and left them submerged at different depths for a period of time."***
>
> — **JAVIER VERDEGUER**, Lead Composite Engineer, CorPower Ocean

But some of those seacoasts are not very friendly to any man-made object. The saline environment is corrosive, and storm surges can transform a sea that is relatively gentle one day to one buffeted by waves that can be tens of meters tall the next. Other wave generation technologies have failed because of the variability encountered in these harsh conditions, and the challenge of designing a system that is effective in extracting power from the ocean while surviving the extremes of 100-year storms. CorPower Ocean knew it needed to address these issues from the beginning.



The buoy is tethered to the seafloor via a patented anchoring technology. A cable links multiple buoys and passes electrical energy into the local grid.
Image courtesy of CorPower Ocean

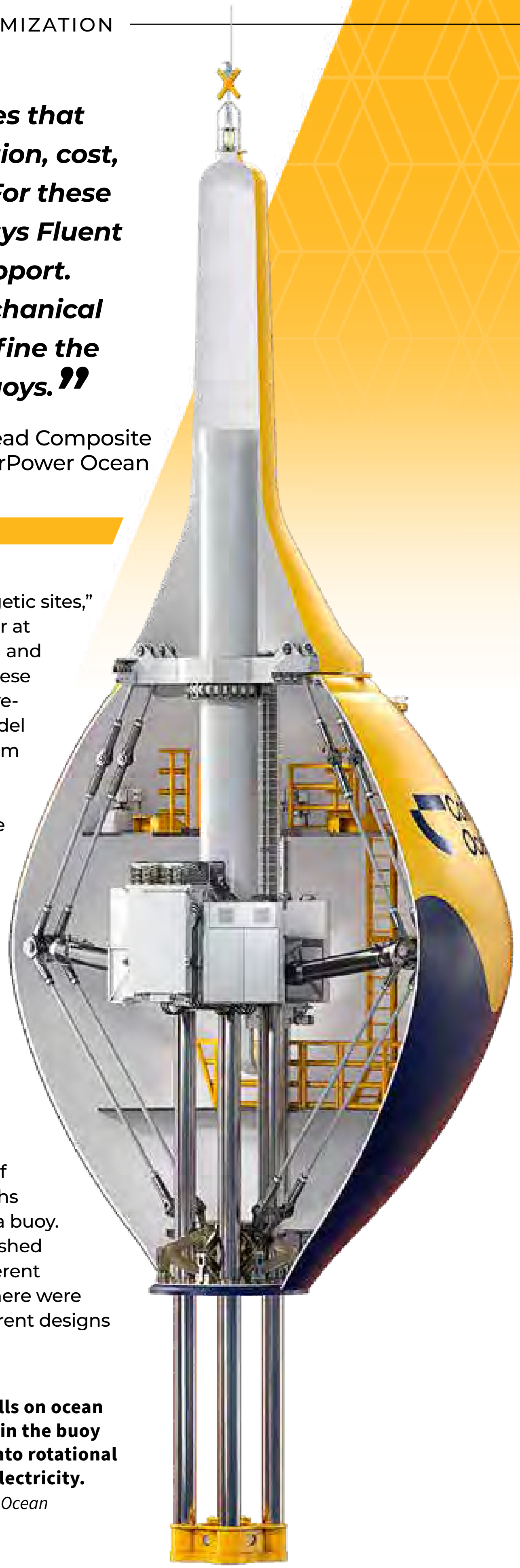
> ***"We needed to design structures that are optimized for energy production, cost, and survival of extreme storms. For these tasks, Ansys Mechanical and Ansys Fluent provided powerful simulation support. The engineering teams used Mechanical and Fluent to model, test, and refine the physical size and shape of the buoys."***
>
> — **JAVIER VERDEGUER**, Lead Composite Engineer, CorPower Ocean

"We use MetOcean data from the most energetic sites," says Ho-Ann Chen, a Composite Design Engineer at CorPower Ocean, "including wave height, period and direction, as well as tides, currents, and more. These variables become inputs for the proprietary 'wave-to-wire' model that CorPower Ocean uses to model expected design loads and energy outcomes from individual locations."

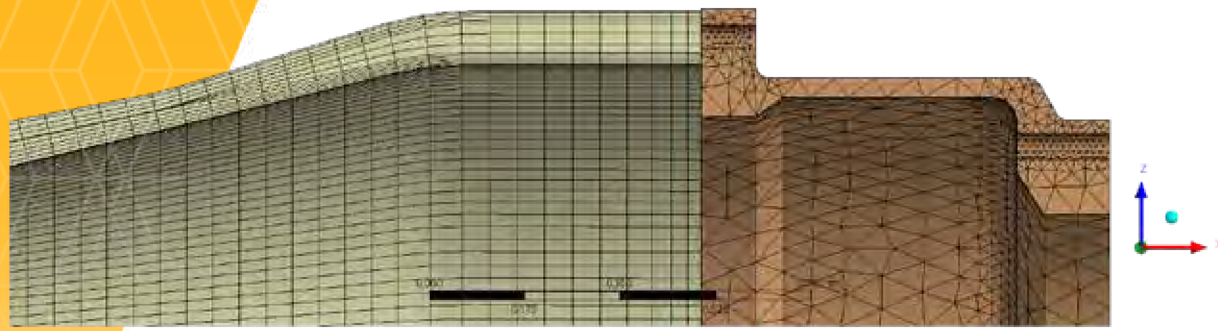
Those inputs also help Chen and other engineers at CorPower Ocean test and refine the design of the buoys and the energy-generating technologies they house.

"We needed to design structures that are optimized for energy production, cost, and survival of extreme storms," says Javier Verdeguer, the Lead Composite Engineer at CorPower Ocean. "For these tasks, Ansys Mechanical and Ansys Fluent provided powerful simulation support. The engineering teams used Mechanical and Fluent to model, test, and refine the physical size and shape of the buoys.

"We used simulation throughout the design phase," Verdeguer continues. "We ran all kinds of simulations involving storms of differing strengths and wave-slamming events against the hulls of a buoy. We looked at simulations where giant waves washed over the buoys and left them submerged at different depths for a period of time. Did they buckle? Where were there structural weaknesses? We looked at different designs



As the buoy rises and falls on ocean waves, technology within the buoy converts wave energy into rotational energy that generates electricity.
Image courtesy of CorPower Ocean



Simulation mesh structure of a composite joint in a CorPower Ocean buoy
Image courtesy of CorPower Ocean

to see how they performed under a wide range of simulated stress loads, evaluated them for fatigue performance, and then used the results of those simulations to optimize the geometry of the buoys with those loads in mind."

CorPower Ocean's designers even used Ansys Composite PrepPost simulations to determine the optimal combination of filament materials and winding patterns that would be used to wrap the composite materials that make up buoy hulls. Using a design of experiments approach, they ran optimization studies to determine which combination of filaments, wound at different angles, would produce the lightest yet strongest hulls. They then passed these optimization specifications to the software controlling the filament winding systems in CorPower Ocean's mobile factory system, which enables them to construct the composite hulls at the location where the buoys are to be deployed. That has eliminated the need to transport the buoys from what would normally be a distant manufacturing facility to the location where they are to be installed.

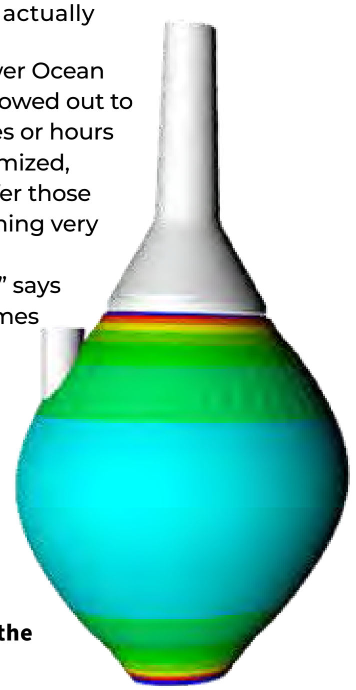
WAVE GOODBYE TO LARGE-SCALE PROTOTYPING

CorPower Ocean has built a half-scale device and operated it at sea, and is progressing with its full-scale proof-of-concept deployment in Agucadoura, Portugal. The company still relies on simulation to avoid building and testing prototypes every time a design refinement is proposed. Early physical tests involving a few key prototypes effectively validated the outcomes projected in simulation. This gave the engineering teams confidence that the outcomes indicated by simulation were predictive of what would actually occur in the real world.

The effect of simulation has been to accelerate design. CorPower Ocean engineers do not need to wait for prototypes to be built, delivered, towed out to sea, and tested; they can see the results in simulation within minutes or hours and reduce the cost of design. This both accelerates delivery of optimized, customer-ready products and ensures that CorPower Ocean can offer those products at a price that customers can cost-justify, even when planning very large-scale deployments.

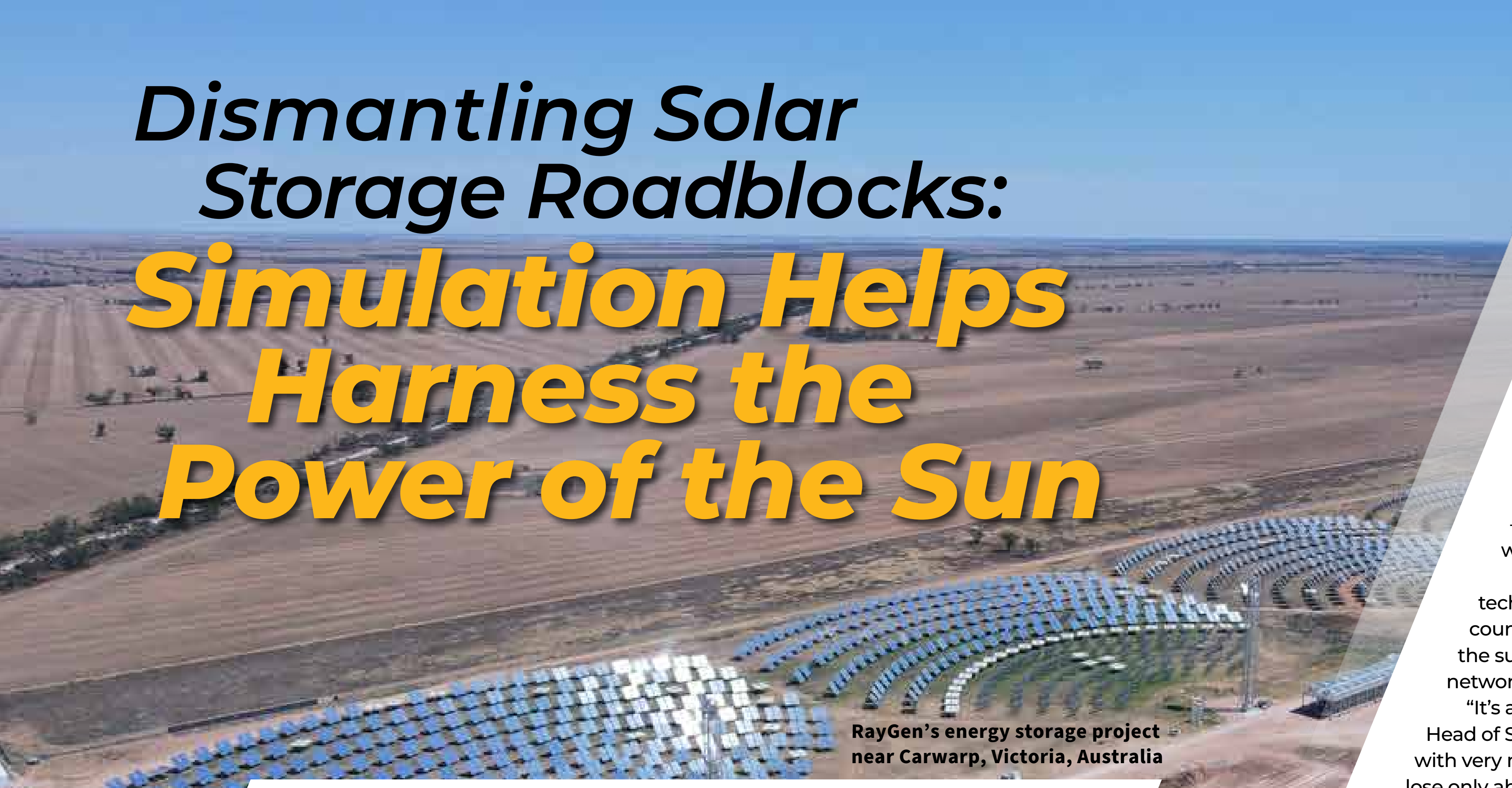
"We're ultimately building large, complex generation systems," says Verdeguer. "The more you can catch problems and optimize outcomes in the design phase, the more effectively you can de-risk a project."

As the world races to embrace cleaner, renewable energy sources — particularly ones that can reliably produce greener energy on a 24/7 basis — speeding up design while simultaneously de-risking the project is definitely a good thing.



Ansys Composite PrepPost modeling of the winding pattern mapping to accurately define the ply definition of the buoy's structure

Dismantling Solar Storage Roadblocks: Simulation Helps Harness the Power of the Sun



RayGen's energy storage project near Carwarp, Victoria, Australia

By Ansys Advantage Staff

Renewable energy sources are expected to play a critical role in the global effort to achieve net-zero emissions by 2050, and solar power is chief among those alternatives, largely because it's inexpensive to implement and can generate electricity in any climate.

But before solar energy can be counted on to help meet internationally agreed upon decarbonization goals — not to mention supporting the three-fold increase in energy consumption that the U.S. Energy Information Administration (EIA) predicts will happen over the next 25 years — two things will have to happen. There will have to be a massive increase in solar power adoption across the globe and significant advancements in generation and storage technology.

In particular, the world will need to overcome the lack of sustainable utility-scale storage, which factors into preventing the widespread uptake of solar energy.

Australian renewable energy company RayGen has taken aim at that problem, developing what it says is the world's largest long-duration energy storage project near Carwarp, Victoria. The project uses 1,200 stand-mounted concentrating mirrors called heliostats to track the sun, generating electricity via high-performance solar photovoltaic (PV) modules and then storing byproduct heat in a water pit the size of four Olympic swimming pools. The heat is later converted to dispatchable electricity. The project is designed to deliver four megawatts (MW) of solar generation and 50 megawatt hours (MWh) of storage, producing electricity on demand via a 2.8 MW Organic Rankine Cycle (ORC) engine, for offtake by Australia's largest utility company, AGL Energy.

RayGen uses Ansys simulation software to model numerous elements of their power plant including the heliostats, the receivers that capture the focused solar energy, and components of the storage system. They work with LEAP Australia, Ansys Elite Channel Partner for Australia and New Zealand, to access Ansys Fluent, Ansys Mechanical, and Ansys Zemax OpticStudio through the Ansys Startup Program.

ENERGIZING THE GRID, DAY OR NIGHT

You've probably heard critics suggest solar energy is good only when the sun is shining, and there's actually some merit to their concern. While homeowners and businesses can capture and store solar energy by way of large, expensive batteries that supply power when the sun isn't out, there hasn't been much in the way of effective, low-cost storage for larger solar arrays like grid-connected solar farms.

Without sufficient storage capacity, many grids are overloaded at midday, causing service providers to rein in their solar generation. As soon as the sun sets or the sky turns overcast, shading the panels, power companies must revert to traditional generation methods. Consequently, the lack of adequate solar energy storage for evening use — when consumer demand is usually at its highest — remains one of the major limitations holding solar technology back from mass adoption.

RayGen may have finally dismantled this roadblock.

As part of their drive to accelerate the transition to renewable energy, the Melbourne-based company has developed an improved approach to solar power — one that they say energizes the grid at all times of the day and night, even when weather conditions are poor.

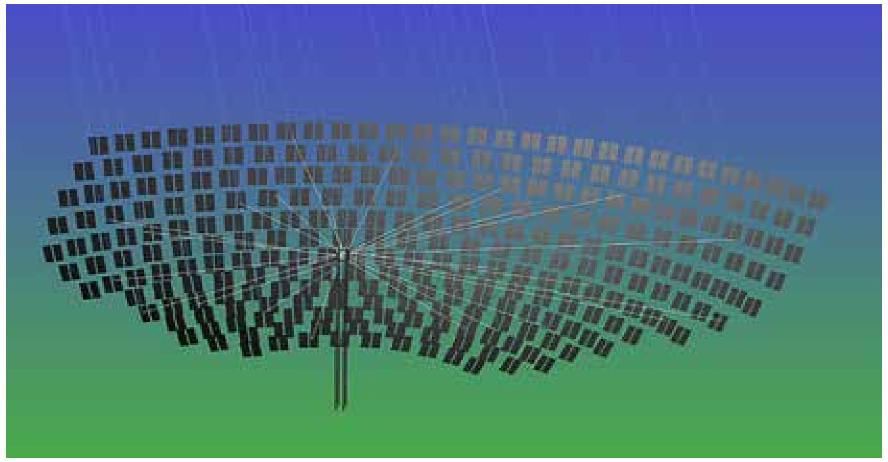
Their technology is based on the concept of "pit thermal energy storage," a technology that RayGen borrowed from the district heating network in Europe, where countries like Denmark use solar thermal energy to heat up large bodies of water during the summer. In the winter, utilities circulate that hot water through the district heating network to warm peoples' homes.

"It's an established technology that we adopted for our application," says Kira Rundel, Head of Strategic Projects at RayGen. "It allows you to store hot water for long periods of time with very minimal losses. So, we store water at 90 °C for days, weeks, months at a time and we lose only about 5% to 10% of that thermal energy over the course of six months. It's an extremely efficient way of storing energy."

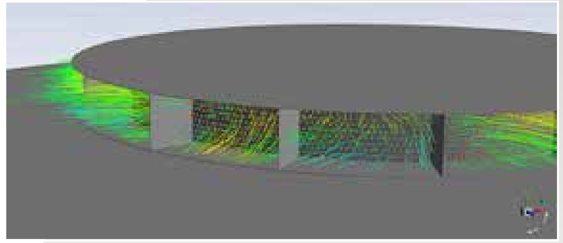
FOLLOWING THE SUN

A sheep pasture that's roughly a six-hour drive northwest of RayGen's home office is the site of the company's flagship project: a next-generation solar power plant and electrothermal energy storage (ETES) system. By pairing what RayGen refers to as their "PV Ultra System" with a water-based storage system, the company has successfully created a first of its kind, high-efficiency facility for both the generation and storage of energy derived entirely from the sun.

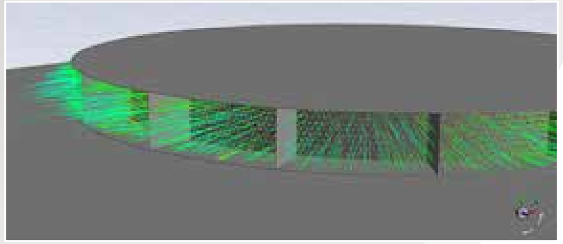
The PV Ultra System is a large field of heliostats that concentrate sunlight toward a single, high-capacity receiver. The heliostats are calibrated to track the sun's position in the sky and to redirect the highest possible amount of solar energy to the receiver. Sitting atop a tower high above the heliostat field, the receiver captures the concentrated sunlight with the help of hundreds of high



Ansys Zemax OpticStudio simulations ensure that the heliostats always deliver as much light and heat to their receivers as possible.



Ansys Fluent simulation of the flow of water through the diffuser in its original design, showing non-uniform flow patterns.



Ansys Fluent simulation of the flow of water through the diffuser in its optimal design, showing more uniform flow to maintain the temperature gradient in the hot and cold storage pits.

performance III-V GaAs solar modules that are approximately two thousand times more powerful than traditional silicon PV panels, under concentration. This configuration allows the PV Ultra System to convert the captured energy into both electricity and heat with 90% efficiency.

RayGen captures that heat — so intense it could melt steel — by circulating cooling water through the solar cells. The water leaves the solar cells at about 95 °C and is held in a massive, insulated water pit, which has the capacity to store up to gigawatt hours (GWh) of energy.

In a concurrent process, a portion of the electricity generated by the PV Ultra System branches off to chill water contained in a second pit, located next to the hot pit. By maintaining a 90 °C temperature differential between the hot and cold water pits, this sector of the RayGen solar power plant has the capability to power an ORC engine that generates and delivers on-demand energy directly to a connected power grid in the same fashion as a geothermal plant. The system has a round-trip efficiency of 70-80% at less than half the cost of a battery-based storage system.

FROM SIMULATION TO SUCCESS

Developing a system as complex as RayGen's solar power plant means taking into consideration everything from electronics and hydrodynamics to the movements of the Earth and sun. While it's conceivable that capable engineers could design such a facility with just pen, paper, and know-how, without the aid of digital simulation it would be a monumentally long, arduous, and costly task.

By employing solutions from Ansys, RayGen's engineers found a faster way.

Optical Simulation

Considering that the sun's rays reach the Earth from different angles and with varying intensity throughout the day and over the course of a year, RayGen turned to Ansys Zemax OpticStudio to ensure that the heliostats always deliver maximum light and heat to their receivers. Without numerical modeling in Zemax, it would have been next to impossible to lock in the best design for each heliostat field.

Thomas Evans, Mechanical Engineer at RayGen, estimates that "using Ansys simulation has saved us months of design time and a considerable number of man-hours. Plus, instead of requiring significant capital expenditure on multiple prototypes and testing phases, we can be confident that we are progressing on the right track, both optically and mechanically, before we commit to constructing anything."

The optical simulation and analysis capabilities of Zemax OpticStudio enable RayGen engineers to run thousands of simulations comparing the effects of adjusting multiple variables such as the size, spacing, and curvature of the heliostat array, as well as its distance from the receiver and the angle of the individual mirrors. By integrating solar data with these simulations, RayGen was able to calculate the optimum arrangement of the entire array and the automation required to maintain each heliostat's optimal orientation over time.

Optical simulation played a part in designing the receiver as well. At each of the receiver's four sides, a flux modifier works to widen the receiver's aperture, capturing any stray light coming from the heliostats and reflecting it back onto the solar modules within it. By incorporating this factor into the system's design parameters, RayGen's engineers were able to secure the highest possible concentration of solar energy at the receiver — an amount 1,000 times greater than the sun itself.

Structural Simulation

Heliostats must perform year-round whether it's hot or cold, windy or calm, raining or desert dry, meaning material properties must be able to withstand considerable climate variations. At the same time, for the PV Ultra System to succeed as a practical, replicable energy solution, the world will need many heliostats, so the economics must be right. Functionality, adaptability, and per-unit cost are all drivers when it comes to selecting materials.

Using Ansys Mechanical to analyze worst-case structural loads, RayGen engineers devised a final heliostat design that requires minimal steel but can withstand adverse weather without becoming compromised or losing its bearing on the receiver.

Computational Fluid Dynamics Simulation

Ansys Fluent helped RayGen engineers develop multiple aspects of their thermal-hydro energy storage system, which comprises two thermally insulated water pits capped by lids — one filled with hot water and one with cold. Fluent computational fluid dynamics (CFD) models optimized the water flow through the copper cooling system located behind the solar modules to keep them at an acceptable operating temperature. The resulting hot water is then delivered to the hot water storage pit.

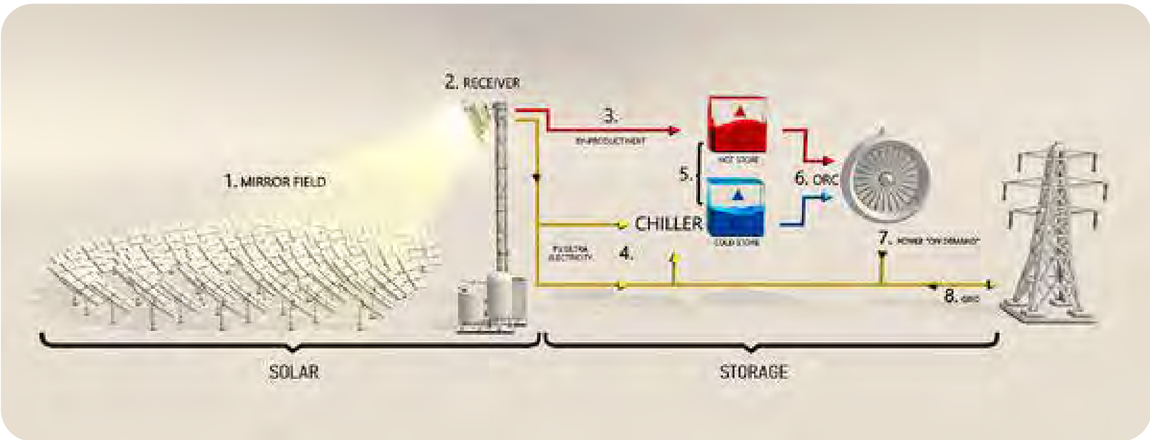
Simulation also enabled engineers to design the large circular diffusers at the inlets and outlets of the thermal-hydro system's hot water storage pits. The diffusers are used to maintain the thermocline within the pit by diffusing the incoming water in a way that preserves the water column's temperature stratification boundaries, which are critical to the storage pit's proper function.

"We have to diffuse water into the pits in a very uniform and low-velocity way so the hot and cool water doesn't mix and disrupt the thermal stratification," says Derek Scott, Product Development Manager at RayGen. "We used Ansys Fluent to determine the optimal design of the diffuser to prevent mixing. What we don't want is a kind of uniform 'hot-ish' pit of water; our process requires access to very hot and very cold water."

After calculating the required size of these diffusers to create an initial digital model, RayGen engineers used Fluent to determine the optimal diameter and spacing of their inlet ports, and to fine-tune the design for their internal baffles and flow screens. Simulations of many design variables on this component led to a final design that allows water to flow uniformly and at the ideal velocity, eliminating the turbulence and reverse flow generated by earlier diffuser models.

THE FUTURE IS BRIGHT . . . AND RENEWABLE

While RayGen envisions similar solar-plus-storage power plants across Australia and, ultimately, the rest of the globe, its proving ground at Carwarp — with its four heliostat fields and receiver towers producing 1 MW of solar energy apiece — lays claim to the title of largest long-duration energy storage project built to date. But RayGen has already announced the site's scaled-up successor. At a location in South Australia, the company plans to erect a multiple-hundred MW plant backed by turbine generation and GW hours of storage duration.



A schematic of RayGen's electricity generation process, including a field of heliostats (mirrors), a receiver, the hot and cold water storage pits, and the Organic Rankine Cycle engine

Fueling Cleaner Transport with the SUN

By **Jennifer Procario**, Staff Writer, Ansys Advantage

We all know that the burning of fossil fuels emits large quantities of carbon dioxide (CO_2) into the atmosphere from various industries, including the automotive industry. And while most of us recognize the decarbonization benefits of electric vehicles (EVs) and autonomous vehicles (AVs), did you know that a large portion of the electricity used to recharge EV batteries is still produced by burning fossil fuels? It would seem, even with our best sustainability efforts, carbon-emitting fossil fuels are unavoidable — until now. Swiss clean energy company Synhelion is powering toward net-zero emissions with technology that avoids fossil fuels altogether.

> ***"Ansys' CFD and FEA simulation allows us to develop, test, and validate extremely complex technology to create sustainable solar fuels. Particularly, in developing our solar receiver, we needed sophisticated and accurate software and Ansys delivered."***
>
> — **LUKAS GEISSBÜHLER,** Head of Thermal Systems at Synhelion

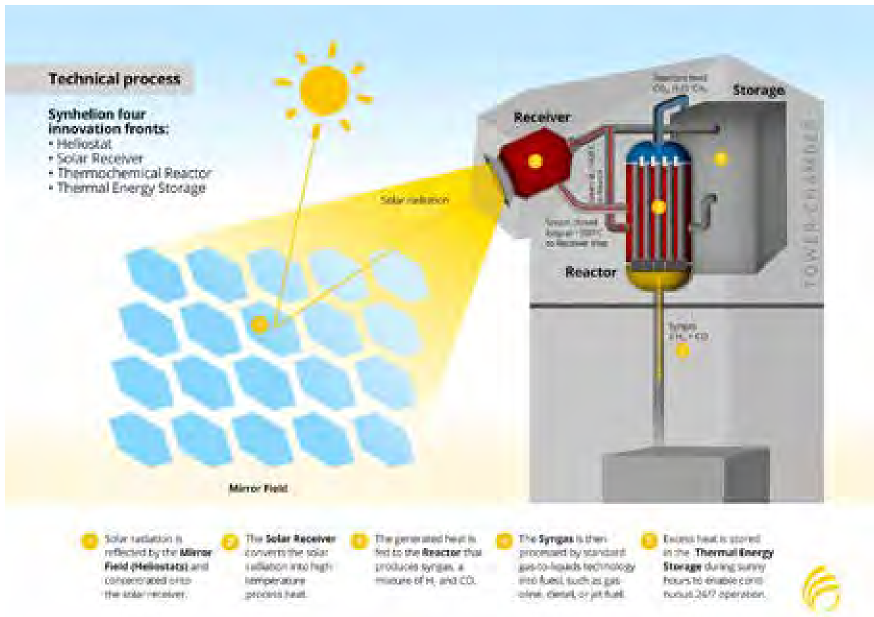
As a member of the Ansys Startup Program, Synhelion is using Ansys' multiphysics simulation and high-temperature solar heat to convert CO_2 and water into synthetic fuels — such as solar gasoline, diesel, or jet fuel — that are compatible with conventional internal combustion engines and aircraft turbines. Through this approach, Synhelion is swapping the traditional petroleum-based process of creating fuel with a method that uses CO_2, water vapor, and solar heat. Further, the innovative "solar fuels" are carbon-neutral, emitting only as much CO_2 as was absorbed during production, which means that no additional CO_2 is emitted into the atmosphere. Synhelion became a member of the Ansys Startup Program in early 2020 via Ansys' Swiss Elite Channel Partner, CADFEM.

TOO HOT TO HANDLE? NOT FOR SIMULATION

Synhelion faced numerous design challenges, including monitoring and assessing the radiative heat transfer in molecular gases, aerodynamic flow distribution, water cooling of components exposed to high heat flux, thermal expansion, and thermomechanical analysis.

To perform the conversion, sunlight is reflected by mirrors and concentrated directly onto a solar receiver where a heat-transfer fluid is heated to temperatures as high as 1,500 °C (2,732 °F). The resulting solar heat is then used to power a thermochemical reactor that produces the synthetic fuel. Synhelion used Ansys' computational fluid dynamics (CFD) and finite element analysis (FEA) software to better understand this complex flow so they could replicate thermo-fluid dynamics to design and validate capable equipment, despite scorching temperatures. To analyze the stresses due to the thermal expansion of the new receiver front, Synhelion engineers ran an FEA simulation in Ansys Mechanical. As a first step, engineers ran CFD simulations of the individual components in Ansys Fluent to approximate temperatures during sun tests. This included gas flow, heat transfer, and the water-cooled components exposed to high heat flux.

In a second step, these temperatures were then used in Mechanical to observe the thermal expansion, thermal storage, and resulting stresses through transient simulations of charging and discharging, along with CFD simulations of flow distribution. Next, the team used CFD to simulate heat transfer to and within



An overview of how Synhelion's Sun-to-Liquid technology works. *Image courtesy of Synhelion.*

Aerial view of the solar tower and mirror field of DLR, Jülich. The mirror field concentrates the solar radiation onto the solar tower and heats up the solar receiver. *Image courtesy of Synhelion.*

the reactor tubes to estimate the chemical reaction and syngas — or synthesis gas — production of the thermochemical reactor while computing and analyzing pressure drop calculations across the reformer tubes.

SCALABLE, SOLAR FUEL

The resulting solar fuel solves various challenges, including being cleaner, more economical, easier to transport, and capable of being stored indefinitely.

"Ansys' CFD and FEA simulation allows us to develop, test, and validate extremely complex technology to create sustainable solar fuels," says Lukas Geissbühler, Head of Thermal Systems at Synhelion in a press release. "Particularly, in developing our solar receiver, we needed sophisticated and accurate software and Ansys delivered. Thanks to Ansys' software, we could reduce prototyping time and build our first industrial receiver more quickly."

As a result of simulation, Synhelion engineers were able to spot changes in the material of exposed components, such as stainless steel and aluminum, to create higher thermal conductivity and improve water-cooling designs to prevent overheating. Further, Ansys software enabled the Synhelion team to overcome design challenges, predict future outcomes, and reduce prototyping time.

Unlike its competitors, by using concentrated solar energy directly in a thermochemical process, Synhelion can use 100% of the light spectrum, rather than employing photovoltaic (PV) panels, where only 20% of the light spectrum can be utilized. Another distinct factor is that Synhelion's thermal energy storage technology enables low-cost solar heat around-the-clock — a significant difference from competitors, who require expensive electricity storage for continuous operation.

Closeup of Synhelion's proprietary solar receiver, which provides the necessary process heat to produce solar fuels. *Image courtesy of Synhelion.*

WHAT'S NEXT, SOLAR SIDEWALKS?

Something like that. Synhelion has had similar success using solar heat to generate cleaner cement, which accounts for approximately 8% of global CO_2 emissions and is the second most used material on earth.

During the cement manufacturing process, burning fossil fuels to heat the kiln accounts for one third of the emissions, while two thirds stem from chemical reactions that release CO_2 as limestone is processed.

Due to a unique feature of Synhelion's solar process heat technology, Synhelion says it offers the ability to power the cement manufacturing process with solar energy, capturing excess CO_2, and ensuring zero emissions are released into the atmosphere.

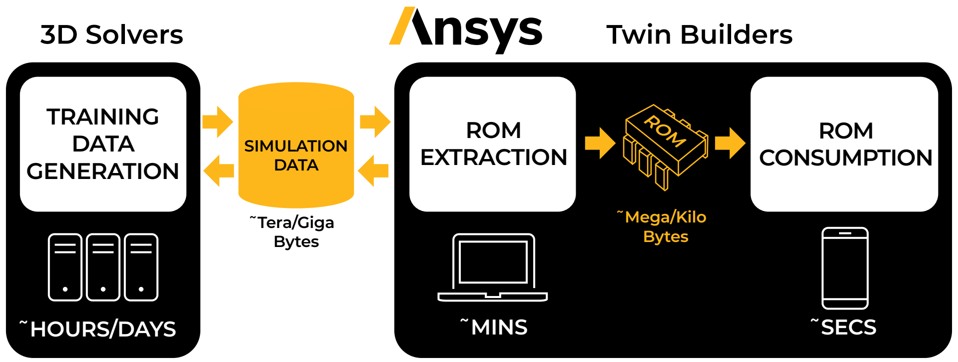
And Synhelion is expanding its technology and impact even further. After raising 22 million Swiss francs last year, the solar fuel pioneer is currently building the world's first plant capable of producing solar fuels at an industrial scale. Industrial solar fuel production will start in 2024.

Digitally Transforming Nuclear Energy

for a More Sustainable Future with the ConnexITy Consortium

By **Lucas Boucinha,**
Lead Product Specialist,
Ansys

Nuclear energy is one of the most sustainable and cleanest forms of energy in the world, with natural origins from the nucleus, or core, of an atom. To create nuclear energy, atoms are split in a thermal reactor, which creates heat that converts water into steam. This high-pressure steam is used to power a turbine linked to a generator and produce electricity. What's more, nuclear electricity production results in near-zero carbon dioxide (CO_2) emissions.



This diagram illustrates how reduced-order models (ROMs) are using machine learning to extract physics from 3D solvers and plug it into the digital twin for accurate physical predictions in real time.

Energy production and consumption are the foundation of many of the current sustainable development goals (SDG) set up by the United Nations. One of these goals, commonly known as SDG 7 or Global Goal 7, aims to ensure access to affordable, reliable, sustainable, and modern energy for all by the end of the next decade.

According to the Nuclear Energy Agency (NEA), the analysis of nuclear energy characteristics within a sustainable development framework shows that the approach adopted by the nuclear energy sector is generally consistent with fundamental SDGs while minimizing environmental impacts. Still, to maintain this consistency and meet rising environmental and safety demands, digital transformation within the nuclear energy industry is a necessity.

The ConnexITy consortium, led by the French multinational utility company Électricité de France (EDF), is leading the charge on this initiative. The partnership of 14 companies, including Ansys, has a shared goal to create new uses and services based on digital technologies to support the digital transformation of the nuclear industry.

For example, to optimize the maintenance and operation of nuclear power plant sites, the consortium posits: What if nuclear power plants had a solution to predict equipment behavior during operation in real time?

To explore this area and make it a reality, partners EDF, Atos, Assystem, Siemens Energy, TechnicAtome, Naval Group, and Ansys are developing a workflow using digital twin technology.

A TWIN FOR A WIN: DIGITAL POWER PLANT SOLUTIONS

The 2020 NEA report "Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders" identifies various technological, organizational, regulatory, and policy key points to accelerate the development of nuclear projects.

Digital transformation is one of three technology approaches highlighted by the report that can be implemented to improve reactor projects and deliver rapid cost reductions in the short term. The digitalization of systems can provide improved engineering methodologies and supply chain integration, enable online monitoring of components, and increase productivity. These advancements can make nuclear plants more cost effective to build and operate, thus facilitating their adoption at a larger scale.

The ConnexITy consortium offers a new and improved solution: a digital twin of a nuclear power plant component. Currently, the consortium is focusing on the turbo generator, which converts mechanical power into electrical at the end of the power generation chain. Due to its important role in the workflow, it is highly beneficial to monitor the turbo generator's behavior during operation to detect anomalies, avoid unscheduled shutdowns, provide insights so the operator can optimize preventive maintenance, and ultimately reduce related costs. Additionally, by monitoring machine behavior, power plant operators can conserve energy and reduce the carbon footprint of many manufacturing processes.

For these reasons, ConnexITy is using Ansys Twin Builder to design a digital twin of the turbo generator that optimizes maintenance and operation in four steps:

1. **MONITOR:** Detect drift with respect to normal asset behavior
2. **IDENTIFY:** Predict root cause of the drift
3. **CONFIRM:** Verify that the predicted failure mode reflects the actual normal asset behavior
4. **ADVISE:** Provide maintenance guidelines and insight

ConnexITy's turbo generator test bench, located at the ConnexLab on the Saclay plateau in Paris, France

According to the Digital Twin Consortium, a digital twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity.

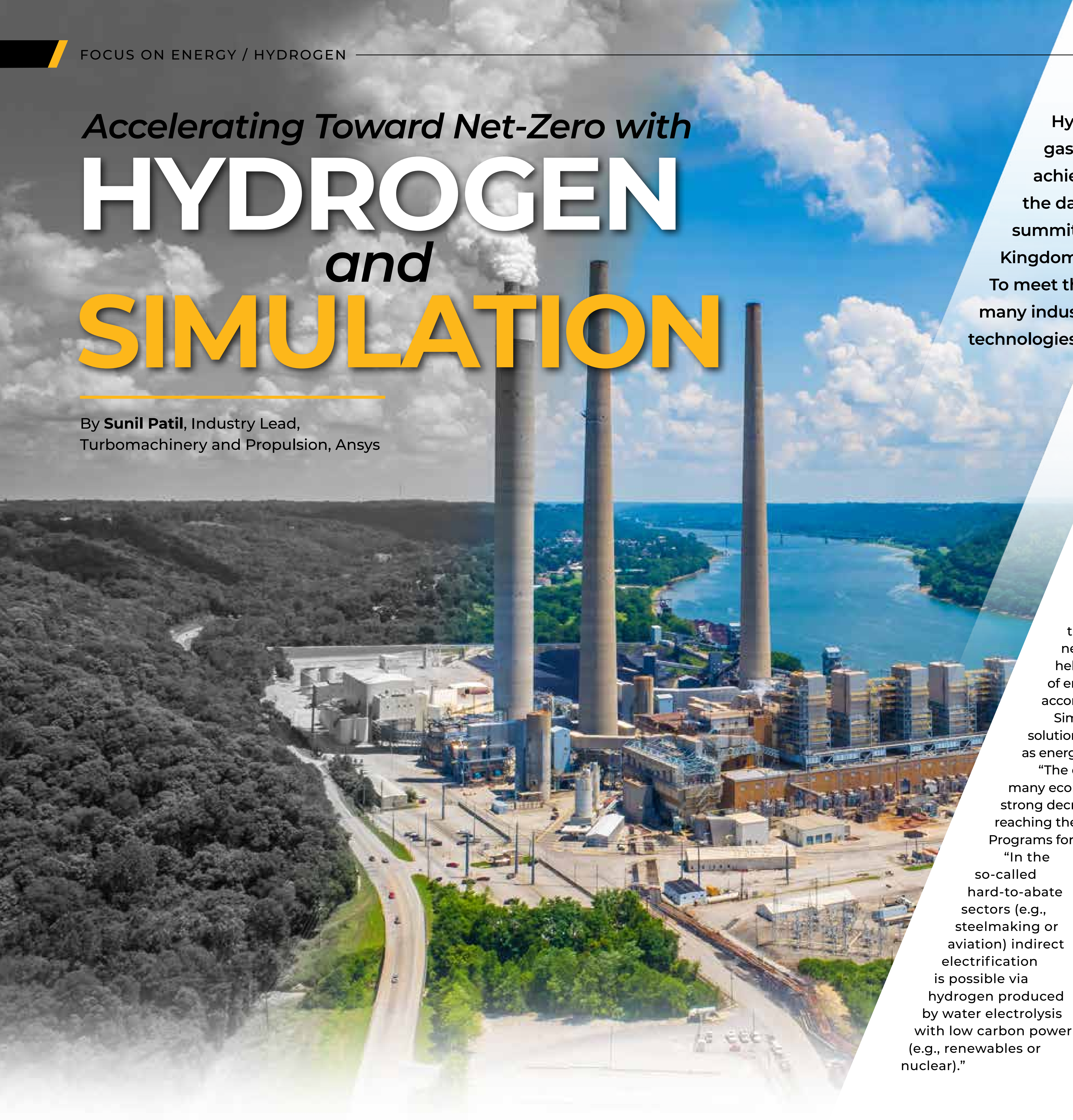
Twin Builder enables teams to build, validate, and deploy digital twins, potentially cutting the time required to create accurate product models in half. This encourages optimized life cycle management and true predictive maintenance, saving costs to help maintain a competitive advantage.

A turbo generator is an electric machine that converts the mechanical power generated by a turbine. In this example, drift represents the difference between two quantities. When looking at the quantity of voltage output for a flux sensor, the drift is the difference between the digital twin model prediction and the measurement of the actual quantity.

The turbo generator's digital twin can predict the health state of the generator in real time by learning from sensor data and reduced-order models (ROMs) of transient electromagnetic behavior. It also uses embedded defect classifiers based on support vector machines (SVMs) to predict probable failure modes. In machine learning (ML), SVMs are supervised models with algorithms that analyze and classify data. In addition, the twin is integrated into Atos' Codex Smart Edge — an industrial internet of things (IIoT) platform — with a web dashboard that allows visualization and interaction between operators and experts.

While the current focus has been on the generator, the same digital twin technology and approach can be applied to other equipment within a power plant. This wider adoption of digital transformation and the resulting progress toward more sustainability is the driving mission of the consortium.

Illustration of the ConnexITy digital twin user experience.



Accelerating Toward Net-Zero with HYDROGEN *and* SIMULATION

By **Sunil Patil**, Industry Lead, Turbomachinery and Propulsion, Ansys

Hydrogen shows promise in helping to reduce greenhouse gas emissions and assisting major economic sectors in achieving their net-zero carbon objectives by 2050. That's the date many countries agreed to during a climate change summit in 2021, and that the European Union, the United Kingdom, and other countries have already made legally binding. To meet that goal will require an overhaul of energy use for many industries and the advancement of a number of emerging technologies, according to the International Energy Agency.

SYNERGY ACROSS INDUSTRIES POINTS TO HYDROGEN ADOPTION

Hydrogen could be a significant part of the solution for carbon neutrality. There are synergies among major industries like aerospace, energy, and automotive to establish a sustainable infrastructure network for hydrogen. It provides many pathways toward sustainability — from energy storage to cleaner energy production and propulsion — while complementing other solutions, such as batteries.

If we look at any of the industrial sectors in detail, we can see the potential impact of hydrogen to reduce greenhouse gas emissions. Let's look at the aviation industry as an example. One proposed roadmap for net-zero carbon proposed for the aviation industry (see Figure 1) shows that only a sustainable fuel, such as hydrogen, provides a realistic path to net zero by 2050. It's important to note that electrification will continue to help reduce emissions, especially with short-haul flights, but more than 90% of emissions in the aviation sector are produced by mid- to long-range flights, according to the Air Transport Action Group.

Similar observations can be made for other sectors where hydrogen-based solutions must play a critical role alongside other important technologies — such as energy efficiency, batteries, and carbon capture — to achieve the net-zero goal.

"The decrease of the carbon content of power and the electrification of many economic activities (e.g., transportation or industry), benefiting from the strong decrease of renewable power costs, are key components of the roadmap for reaching the 1.5 °C target by 2050," says Claude Heller, former Director of Group R&D Programs for Air Liquide who is now a Senior Advisor for the Hydrogen Economy.

"In the so-called hard-to-abate sectors (e.g., steelmaking or aviation) indirect electrification is possible via hydrogen produced by water electrolysis with low carbon power (e.g., renewables or nuclear)."

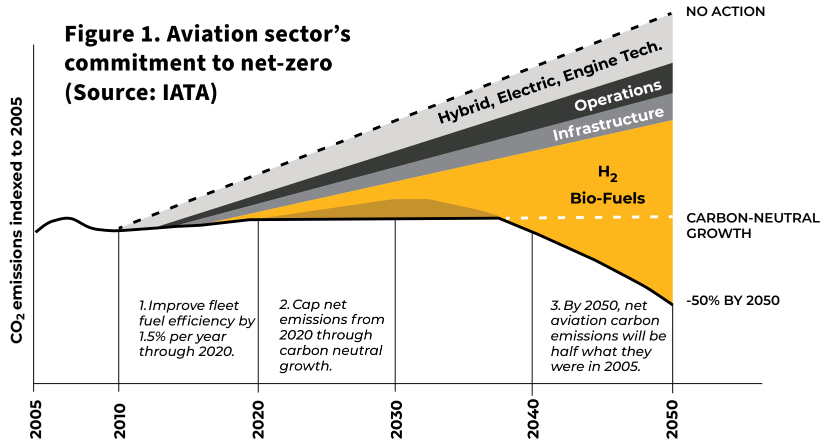


Figure 1. Aviation sector's commitment to net-zero (Source: IATA)

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"The decrease of the carbon content of power and the electrification of many economic activities (e.g., transportation or industry), benefiting from the strong decrease of renewable power costs, are key components of the roadmap for reaching the 1.5 °C target by 2050."

— **CLAUDE HELLER,** Senior Advisor for the Hydrogen Economy

THREE KEY CHALLENGES IN HYDROGEN DEMOCRATIZATION ACROSS INDUSTRIES

Three major challenges with hydrogen democratization are cost, infrastructure, and scale.

1. COST

The cost of green hydrogen production (hydrogen produced using renewable energy) is around $5 per kilogram, which has made it less competitive compared to carbon-heavy fuels such as natural gas or kerosene. The high cost is linked to infrastructure investment and demand, which is now getting a boost because of regulations and proactive actions being taken by governments around the world.

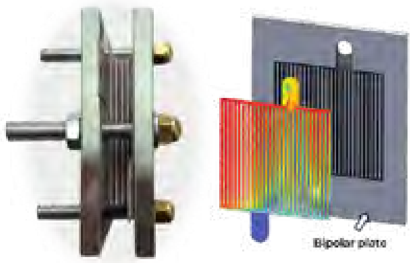


Figure 2. A proton exchange membrane water electrolysis stack for hydrogen production (left) with optimized cell design through Ansys simulation (right)

Investment in green hydrogen now exceeds $1 billion per year. The biggest investment, globally, has come from the European Union, which accounts for more than half of hydrogen-based project investments in the early part of this decade. The U.S. Department of Energy (DOE) launched the Energy Earthshots Initiative in June 2021 for an accelerated energy transition. The first Energy Earthshot, called Hydrogen Shot, targets lowering the cost of green hydrogen to $1/kg by the end of the decade.

2. INFRASTRUCTURE

With a significant investment in a hydrogen ecosystem, technical challenges related to hydrogen are back in focus. However, significant design challenges at each stage still exist — from its production to storage and transportation, to its end use. One of the major challenges at all stages is the energy efficiency of the devices involved. Fuel cell efficiency currently ranges between 40% and 60%, while the average electrolyzer efficiency is 60%. Significant improvements in efficiency are possible but time-consuming in a traditional build-test-improve design environment.

For example, hydrogen shows great promise in decarbonizing aviation and power generation gas turbines because of its high energy density and ability to burn lean. However, burning hydrogen in engines poses several technical challenges, including flashback, acoustic instabilities, autoignition, and flame holding inside the burner.

Because of its low molecular weight and density, storage of hydrogen in a compact space is also a big challenge. It needs to be heavily compressed or stored in cryogenic/liquid form. The storage tank design, whether it's flying in the sky on a plane or riding in the back of fuel cell vehicle on the ground, requires special consideration for embrittlement, leakage, and associated safety risk.

3. SCALE

Finally, there are end-use challenges related to scaling hydrogen. The current system size and weight of fuel cells are large, especially for aerospace and automotive applications. Their durability and reliability need to be improved for most transportation applications. Thermal, water, and air management are also challenges when attempting to keep the size of the heat exchanger and overall system small.

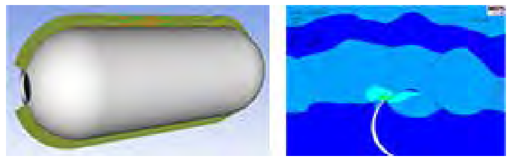


Figure 3. A cryogenic liquid/compressed hydrogen tank design using Ansys Composite PrepPost (ACP) on the left and embrittle/crack analysis in Ansys Mechanical on the right

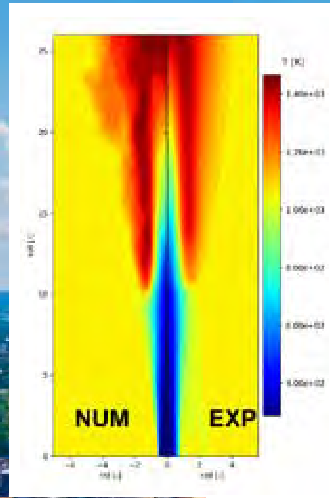


Figure 4. Ansys Fluent computational fluid dynamics (CFD) predictions for hydrogen combustion and its validation against experimental data

"Current hydrogen technologies (e.g., electrolysis or fuel cells) are mature enough to engage the hydrogen economy at scale for decreasing the costs," says Heller. "In parallel, there is still a need to improve processes in order to decrease the costs beyond the size effect. For that purpose, a better understanding — and the modeling of electrochemical reactions at molecular scale and processes at system levels (e.g., cells or stacks) — is essential."

SIMULATION TECHNOLOGY ENABLES HYDROGEN ADOPTION

Ansys technology enables you to overcome the challenges associated with hydrogen by improving performance at every phase of its ecosystem and accelerating new technology development to address the cost and scale conundrum. For example, ENHIGMA, a national project that involves various companies along with technological and research centers, used Ansys technology to manufacture low-cost, energy-efficient, and durable proton exchange membrane (PEM)-based electrolyzers and fuel cells. As shown in Figure 2, Centro Nacional del Hidrógeno (CNH2) researchers optimized the PEM cell stacks using flow simulations in Ansys Fluent.

Ansys simulation technology is used for individual cell design, cost-effective and lightweight material selection, cell-stack optimization for energy efficiency, and thermal management of the overall fuel cell and electrolysis system.

Cryogenic storage and transport are at the core of the hydrogen ecosystem. Ansys composites solutions can be used to design cryogenic vessels while closely mimicking their manufacturing process. The composite failure tool in Ansys Mechanical enables designers to evaluate potential failure modes and failure locations in-depth using advanced composite failure criteria such as Tsai-Wu, Puck, and LaRC. It can further be used to understand the effect of embrittlement and crack initiation and propagation, as shown in Figure 3.

Hydrogen-powered gas turbine engines provide the most promising path for decarbonization efforts in the energy and aviation sector. The most complex technical challenges of hydrogen combustion — such as flashback, acoustic instabilities, and autoignition — can be characterized and addressed with high-fidelity simulations. Figure 4 shows validation of CFD simulation methodology in Fluent for hydrogen combustion against experimental data.

Finally, advanced digitalization technologies, such as digital twins and reduced-order models (ROMs), can be used to optimize the operations of hydrogen-based systems. ROMs are simplifications of high-fidelity, complex models. They capture the behavior of source models so that engineers can quickly study a system's dominant effects using minimal computational resources.

A typical hydrogen production system or hydrogen-based fuel cell plant contains many components. Most of these can be represented by a simplified model, but most critical parts — such as fuel cells or PEM-cell stacks — can be represented by a ROM derived from Ansys 3D physics solvers. ROM creation for this digital twin is enabled by Ansys optiSLang, which automates the simulation toolchain and connects to algorithms for robust design optimization (RDO). With connection to live sensor data, this digital twin can monitor and optimize operations while enabling predictive maintenance.

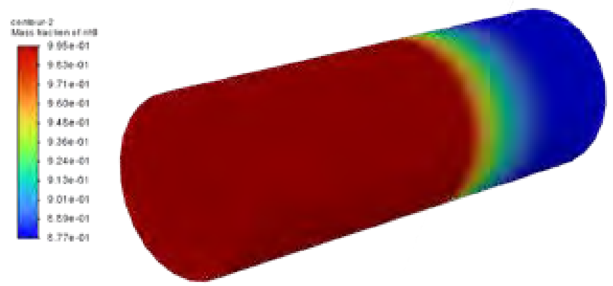
By empowering engineers to explore more hydrogen design options faster and more affordably, simulation will help meet the top challenges related to increased hydrogen adoption. Being able to design and test hydrogen-related technologies in a virtual environment speeds time-to-market, which is critical as governments and industries rush to meet the 2050 net-zero carbon goals.

Amogy Promotes Ammonia Power

Amogy's ammonia-powered 100 kW tractor

By **Laura Carter**, Staff Writer, Ansys Advantage

Could ammonia be a real game changer in the race to net zero? Amogy, a sustainable energy startup, believes it's an important clean energy source for heavy industries, including maritime and power generation. Citing its unique properties, the company sees an immense opportunity. Today, its ammonia-based, emission-free, high energy-density power solutions are well positioned to shape a more sustainable future.



Using Ansys Fluent's User Defined Function capabilities, the Amogy simulation team replicates catalyst characterization experiments to validate customized NH_3 decomposition rate laws provided by the Amogy materials team.

> ***"Ammonia will be pivotal in the integration of hydrogen into green transportation solutions of the future. This carbon-free hydrogen carrier is more energy dense than compressed or liquefied hydrogen, and more than five times denser than a conventional lithium-ion battery. With help from the Ansys Startup Program, we're realizing all of these advantages in an ammonia-based, sustainable technology to deliver a lower-cost, higher-power fuel alternative that's suitable and more sustainable for power-demanding heavy transportation applications."***
>
> — **YOUNG SUK JO**, CTO at Amogy

Founded in 2020 by four Massachusetts Institute of Technology Ph.D. alumni with a shared vision, Amogy aims to accelerate the global journey to net-zero emissions with its ammonia-to-power technology. They've secured the support of Amazon's Climate Pledge Fund — as well as Temasek, SK Innovation, Aramco Ventures, Mitsubishi Corporation, and Mitsubishi Heavy Industries — to accomplish this.

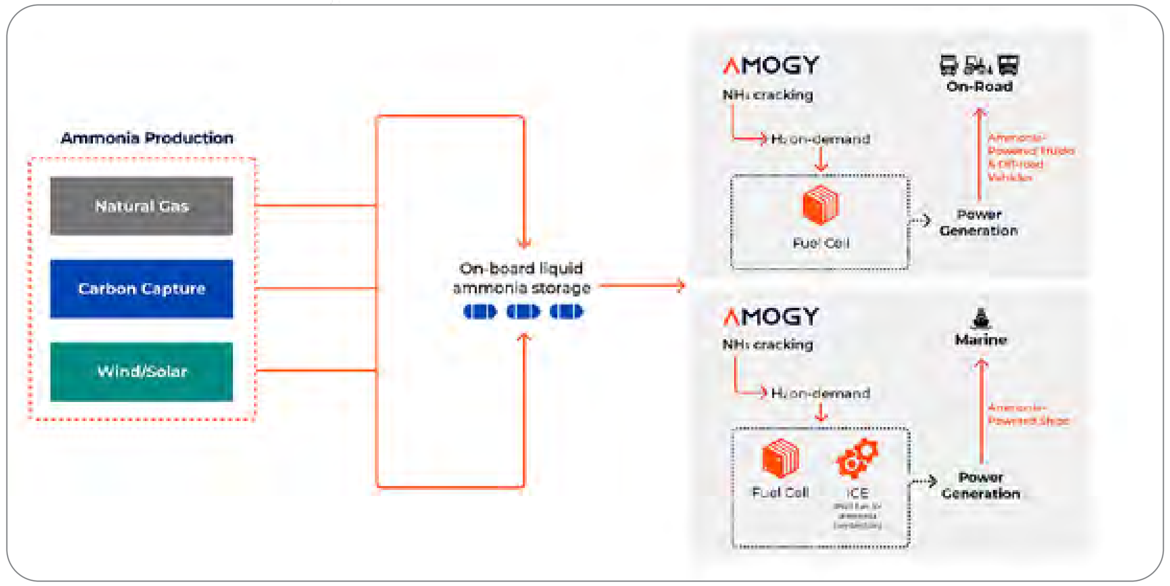
Specifically, Amogy is building a novel, portable, carbon-free energy system that uses ammonia as renewable fuel. The technology has many potential applications, including shipping, power generation, hydrogen generation, and more. So far, this scalable, zero-emissions energy system has been demonstrated in a 5 kW drone, a 100 kW mid-sized tractor, and 300 kW semi-trucks — thanks, in part, to Ansys simulation software.

"Simulation is one of the critical enablers to scaling our technology to meet this objective," says Matt Montgomery, Combustion and Simulation Manager at Amogy. "Because we work on a very large scale, analyzing product designs and testing small changes within a simulation environment up front helps us move through product development cycles faster. Using Ansys software within a digitized workflow increases our engineering productivity to realize our vision of a decarbonized transportation system much faster."

IN 'STARTUP MODE' WITH ANSYS

Right from the start, simulation has been an important part of Amogy's development strategy. Early on, Amogy discovered Ansys Fluent's advanced capabilities and began using it as a more viable alternative to meet its simulation needs for model upgrades.

Of course, in "startup mode," new product



The science behind Amogy's technology

development is Amogy's main goal. The ability to support prototyping and design decisions with high-fidelity simulation is extremely important, as the data resulting from analysis will ultimately inform new prototypes that lead to future products. Comparing simulation software, Amogy needed to identify a solution that enabled quick, efficient simulation run times at a comfortable price point.

Cue the Ansys Startup Program, which is specifically geared toward early-stage startups with limited funding and revenue at their disposal. The program provides full access to Ansys multiphysics simulation software and high-performance computing (HPC) resources at an affordable price to give startups the support they need in a competitive landscape.

"The Startup Program enabled us to test a variety of Ansys products and implement them into our workflow at a time when we could not afford the commercial license pricing," says Montgomery. "As a result, we were able to leverage Ansys resources during the initial growth of the company, which helped us get to the point where we could afford the commercial licenses ourselves."

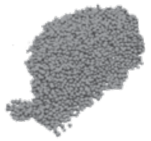
BETTER TOOLS YIELD BIGGER INSIGHTS

Making the switch to Ansys software helps Amogy address several key challenges. First, Ansys multiphysics tools enable its development team to study the effects of different design features in a digital environment without requiring a physical prototype, accelerating the prototyping process to reach design decisions faster. These same tools also help them zero in on expected product temperature profiles that would otherwise be hard to measure. They also offer a more in-depth look at the physical phenomena Amogy technology relies on

Amogy's ammonia-powered 300 kW semi-truck

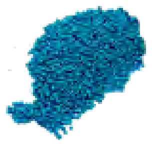
THE 'COLORS' OF AMMONIA

Producing ammonia involves the reaction of nitrogen with hydrogen to form NH_3. Nitrogen is readily available in the atmosphere. The method of generating hydrogen determines the "color" of the ammonia process. For gray, blue, and turquoise ammonia, the hydrogen source is a fossil fuel. For pink/yellow and green ammonia, water is the source of hydrogen.



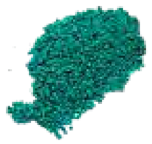
GRAY

Gray ammonia results from reacting nitrogen from the atmosphere with hydrogen obtained by steam reforming of methane. The steam reforming process is estimated to contribute 1-2% of greenhouse gas emissions.



BLUE

Blue ammonia involves adding a carbon capture step to the gray ammonia process. While fossil fuels are still part of the process, the carbon capture step leads to less CO_2 escaping into the atmosphere.

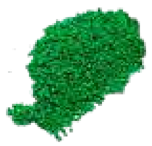


TURQUOISE

Turquoise ammonia obtains hydrogen by burning methane at elevated temperatures with no oxygen present to prevent the formation of CO_2. The result is solid carbon and hydrogen gas.

PINK/YELLOW

Pink/yellow ammonia uses nuclear power for the electrolysis of water to produce hydrogen gas.



GREEN

Green ammonia uses renewable energy sources to generate electricity to split water into hydrogen and oxygen by electrolysis.

Source: S&P Global Commodity Insights (https://www.spglobal.com/commodityinsights/en/market-insights/blogs/agriculture/053123-fertecon-ammonia-australia-india-china)

> ***"Simulation is one of the critical enablers to scaling our technology to meet this objective. Because we work on a very large scale, analyzing product designs and testing small changes within a simulation environment up front helps us move through product development cycles faster. Using Ansys software within a digitized workflow increases our engineering productivity to realize our vision of a decarbonized transportation system much faster."***
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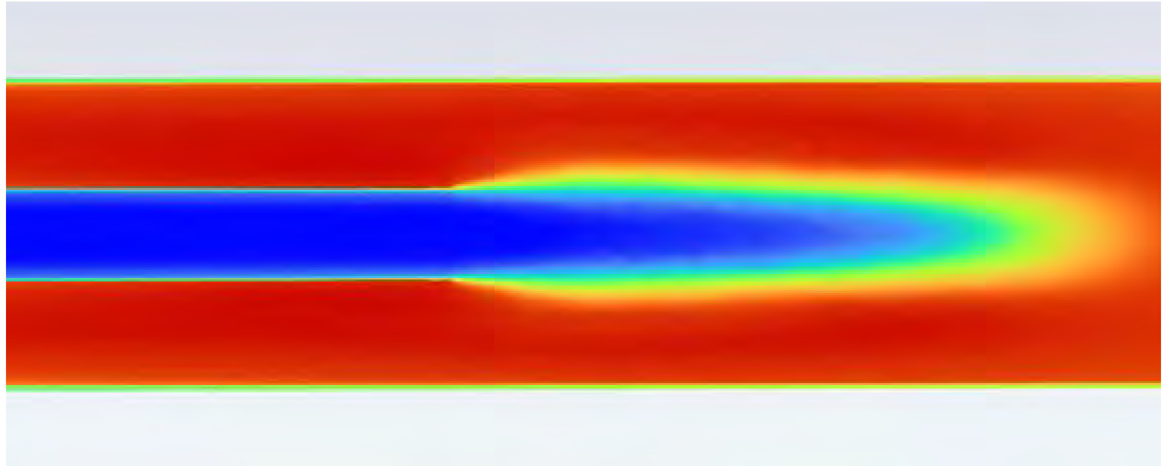
> — **MATT MONTGOMERY**, Combustion and Simulation Manager, Amogy



The Amogy simulation team simulated a diffusion flame using Ansys Fluent's partially premixed combustion model, as part of the conceptual design phase for Amogy's NH_3-powered tractor demonstration.

to understand various factors such as the properties of its materials.

Amogy relies mainly on Ansys Fluent and Ansys Mechanical. Both solutions have become an integral part of an extended workflow that begins with the analysis of a design concept before the design is sent out for fabrication.

Initial activity can range from a single simulation to examine some aspect of a flow field to a week-long optimization study on a specific design feature. Within Amogy, designers provide the simulation team with a computer-aided design file. From there, the team meshes the design in Fluent Meshing and generates case files in Fluent.

Results from these activities are then used to update certain features in the design, and the process repeats until the design is ready for fabrication. This saves time and cost associated with physical prototyping.

SHORTER RUNTIMES SAVE ALMOST AN ENTIRE DAY'S WORK

Ansys solutions were used to improve product design through the study of combustion, surface and volumetric chemical reactions, and heat transfer. This analysis involved anywhere from 1 million to 20 million elements. Simulations were enabled by cloud HPC clusters and local desktops for large and small simulations, respectively, to improve simulation run times.

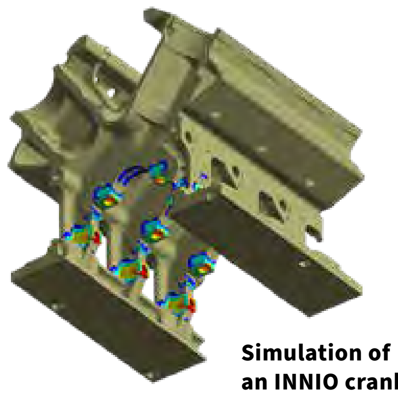
"Before Ansys, we had a simulation of roughly 1-2 million cells running on about 300 cores, which took almost 24 hours to converge," says Christopher Stanczak, Mechanical Engineer at Amogy. "Using Ansys software, the same simulation could be completed in a few hours on our local machine. Since we run our large simulations on HPC clusters on the cloud, the time savings results in cost savings, as short runtimes mean less time paying for the cluster."

INNIO's headquarters in Jenbach, Austria.

Building Efficient Power Solutions by Connecting Digital Threads

By **Tim Palucka**, Managing Editor, Ansys Advantage

Sometime around 2014, Frédéric Bussières, then a simulation engineer at GE Power, was caught up in a company initiative to accelerate first-time-right solutions for the company's most critical components using early visions of the emerging concept of a digital thread.



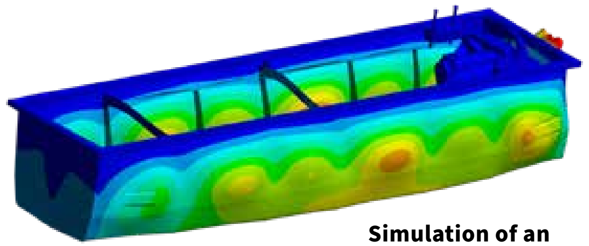
Simulation of an INNIO crank case

"I was writing in JavaScript to automate the creation of models — trying to really automate anything and everything," he recalls. "But building methods at the same time as trying to automate them is very difficult. So, it was a little too much too early, and it earned me the nickname of 'Digital Fred,'" he says with a laugh. "It stuck."

> ***"Simulation makes us more efficient at protecting our customers' interests, by tackling innovation and making sure they're competitive and profitable."***
>
> — **FRÉDÉRIC BUSSIÈRES,** Senior Team Manager, Global Mechanical Simulation, the INNIO Group

Today, Digital Fred is Senior Team Manager, Global Mechanical Simulation of the INNIO Group, headquartered in Jenbach, Austria. INNIO's Jenbacher technologies deliver efficient, sustainable distributed heat and power for commercial, industrial, and municipal applications.

Jenbacher engines are known for their efficiency and robustness and run on a broad range of sustainable energy sources, from pipeline gas to hydrogen. These include other renewable gases such as biogas, biomethane, landfill gas, and sewage gas, as well as special gases such as syngas (a blend of CO and H_2). To date, over 24,000 Jenbacher engines have been delivered in about 100 countries.

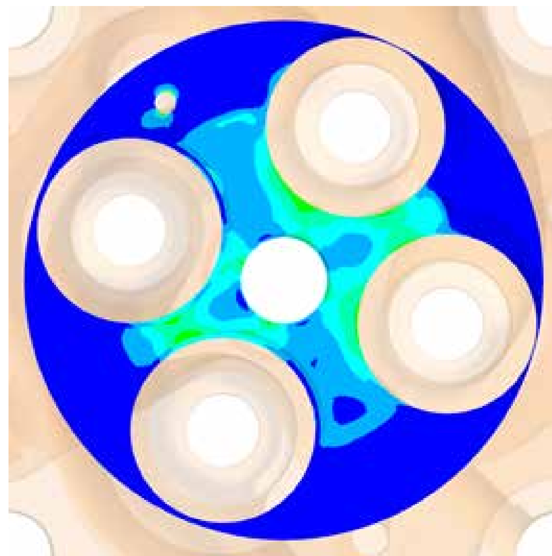


Simulation of an INNIO oil pan

"For INNIO, sustainability means an everlasting pursuit of innovation to develop energy solutions of higher efficiency and lower emissions," Bussières says. "Decarbonization, with hydrogen or other fuels, also means overcoming new material challenges presented by these innovations. For instance, this means dealing with higher temperatures, more challenging combustion mechanisms, and potentially new failure modes. All that puts pressure on our engineering methods."

To relieve some of that pressure, INNIO uses Ansys Mechanical and Ansys Workbench to simulate static structural, steady-state thermal, transient thermal, structural optimization, harmonic analysis, and random vibration properties of their engine models. They have also used Ansys LS-DYNA explicit simulation to determine the response of materials to short periods of severe loading. Recently they adopted Ansys Granta materials tools to ensure they are using the best materials for each component. For simulation of fluids, they use Ansys CFX and Ansys Fluent for waterside boundary conditions.

Perhaps more importantly, Bussières and his team have used Ansys Workbench and the Ansys ACT and Ansys Parametric Design Language (APDL), along with other scripting tools, to create digital engineering workflows that automatically integrate these simulations in a digital thread. Instead of having to manually export data from one simulation into the next step in the simulation chain, scripting makes the workflow — data transport and movement from one type of simulation to the next — streamlined, automatic, and therefore faster and more efficient. It gives engineers more time to focus on the end goal, with seamless iterations and faster innovation rhythm.



A simulation of the gradient of equivalent plastic strain (D_{PEEQ}) in an INNIO component

Bussières manages a team of engineers that is responsible for all engine platforms, including platforms featuring multiple cylinder counts and numerous product configurations. Coordinating the work of such a team of engineers and projects is made easier and more efficient with digital engineering. INNIO has been innovative in optimizing the parameterization process, inventing better ways to display simulation results, selecting the right material for the application, and much more. Ansys simulation plays an important role in the team's efforts.

AUTOMATING OPTIMIZATION

Parameterization is what started Bussières in simulation. He soon found that the capability of automation and programmed sequences of simulations to investigate a wide range of parameters automatically and determine an optimal configuration for a component was essential to engineering success.

"The first kind of assignment I had using Ansys simulation solutions was purely parametric, so I had to develop very extensive APDL scripts for building geometry for FEA (finite element analysis) models from scratch — from zero to a report basically," Bussières says. "And then on top of that, running designs of experiments (DOEs) and optimization simultaneously — a process of fully parameterizing a piece of work from cradle to grave. When I started using Ansys Workbench, I recognized that there was a roadmap to further improving this process. So, by parameterizing the geometry and environment, parameterizing just about anything and adding customization on top of it, I feel like I am steering the design somewhere, and gaining ownership of the design space."

INNIO uses CADNexus to produce designs along with Ansys Mechanical FEA software in an Ansys Workbench environment. The Ansys Workbench platform enables them to integrate data across engineering simulations to create more accurate models more efficiently.

"Combining Workbench and CADNexus to bring parameterization to the FEA world has been a really foundational benefit of Ansys' approach versus that of their other competitors," he says.

The combination has paid off for INNIO.

"The original cycle time of a cylinder head analysis was too long," Bussières says. "It would take us weeks to get to a point where we had documented and understood what an iteration looked like, from fluids to the structural results and lifing. And now we can perform all these multiphysics simulations in a couple days. So, within a week we've got several concepts, on which we can further iterate at a greater speed. That makes us a lot more efficient and successful, and gives us confidence in the robustness of our solutions. I think that's thanks to our ability to explore the design space, and iterate quickly, and learn fast from what we put together."

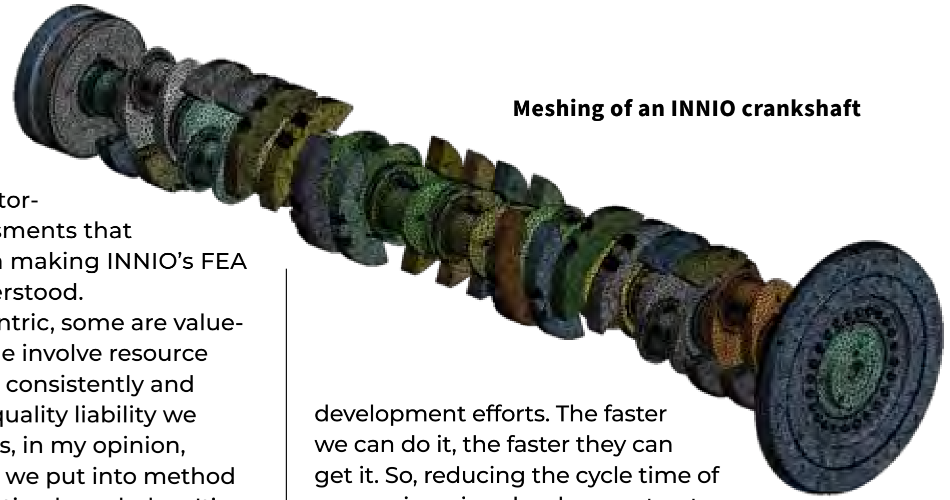
Digital engineering, specifically maintaining the chain between CAD and FEA, is key to INNIO's efficiency.

"When we follow our internal engineering process, it guides us toward a coupled interaction between the designer and CAE," Bussières says. "With Workbench, we have a very robust way of bringing new geometry in and empowering the analyst or the CAE engineer to own that design in a certain sense, to iterate on it, which is paramount to analysis-led design."

CONNECTING THE DIGITAL THREAD TO THE BUSINESS

Given the size of the CAE team at INNIO, the role of analysts is far more than one of displaying results with colorful pictures. INNIO's "need for speed," as Bussieres puts it, requires quality and efficiency to be encapsulated into methods.

"We needed to move away from colors and gut feeling assessment to metric driven solutions," he says. So, starting in 2016, they used Ansys ACT to develop a digital toolbox containing 20 tools for translating the shades of the rainbow from FEA results into something that shows the results more factually and effectively.



Meshing of an INNIO crankshaft

To improve the communication of results within the team, Bussieres developed key- performance-indicator-based (KPI-based) assessments that have been very helpful in making INNIO's FEA models more easily understood.

Some KPIs are cost-centric, some are value-creation centric, and some involve resource demand. "We've reduced consistently and considerably the cost of quality liability we had in the past. And that's, in my opinion, thanks to the investment we put into method development, into simulation knowledge. It's been a long journey, but the vision is paying off. All these customized tools are meant to translate FEA results into something more meaningful," Bussières says. "They divert your attention away from the 'rainbow' colors of a result to a more metrics-based and KPI-based assessment."

THE BENEFITS OF SIMULATION

"Simulation makes us more efficient at protecting our customers' interests, by tackling innovation and making sure they're competitive and profitable," Bussières says. "By protecting the longevity and life cycle of their assets, and by providing retrofittable innovation along the way, we are preserving their present and future return on investment. We do that by having faith in the results of our simulation and development efforts. The faster we can do it, the faster they can get it. So, reducing the cycle time of our engineering development gets our products to the field quicker, and it helps us differentiate ourselves from the competition."

Such a commitment toward engineering methods is part of an initiative called "Future Engineering." Andreas Kunz, INNIO's CTO, reflects on the matter: "Increasingly demanding performance from our products requires equal commitment to innovation and engineering excellence. Future Engineering is our way to translate our vision for a sustainable future with development efforts, using cutting-edge methods and simulation tools".

"It's been exciting," Bussières concludes. "We can proudly say that our work enables reducing the cost of quality while also creating future value. Savings in the future and value in the future —that's double the benefit."

HYDROGEN: A MATERIAL DIFFERENCE

Burning hydrogen, biogas, and other sustainable fuels in engines often comes with thermal and mechanical challenges that can be conveniently assessed by simulation.

"What does it mean to run on 100% hydrogen, in terms of flame temperature, in terms of combustion chamber temperature, in terms of potential damage to materials?" Bussières asks. "How do we need to change our engineering methods and development strategy? What are going to be the technical and commercial bottlenecks? We're currently working on answering these questions."

Part of INNIO's "Future Engineering" initiative focusing on engineering excellence is a three-phase roadmap to adopt Ansys Granta materials solutions across the company. Ansys Granta MI provides a comprehensive library of material properties that can be easily imported into structural simulations to determine the effects of changing conditions. The library maintains a single source of truth for materials properties to ensure that every engineer or designer in the company is using the same materials data.

In addition, INNIO engineers can search the database for alternative materials that meet all strength and temperature requirements while being lighter in weight, less expensive, or more readily available on the global market. Substituting these materials for ones currently in use can reduce costs for INNIO and save money for their clients.

Accelerate Zero-Carbon Energy

By **Graziella Alves**, Manager, Product Marketing, Ansys

ENGIE Lab CRIGEN is ENGIE's corporate R&D center dedicated to greener gases (hydrogen, biogas, liquefied gases); new energy uses in cities, buildings and industries; and emerging technologies, including digital transformation, artificial intelligence, drones, robots, nanotechnologies, and sensors.

To guide its customers toward a greener and more ecological energy source, ENGIE Lab CRIGEN relies on Ansys' digital twin technology to accelerate the zero-carbon energy transition for its customers.

"The Ansys reduced-order modeling approach allows us to go from simulation times of several hours, or even days, to a few seconds. The use of digital twins, and in particular ROM technology, completely changes the way digital simulation is used."

— **NICOLAS MEYNET**, Multiphysics Simulation Expert, ENGIE Lab CRIGEN

Meet Nicolas Meynet, Multiphysics Simulation Expert at ENGIE Lab CRIGEN since 2016. Meynet and his team are using Ansys Twin Builder to develop an engineering platform that delivers real-time 3D high-definition results from CFD (computational fluid dynamics) simulations.

REDUCE SIMULATION TIME FROM HOURS TO SECONDS WITH REDUCED-ORDER MODELING

One of the main missions of ENGIE Lab CRIGEN is to develop new smart and connected technologies to reach its "100% green gas" objective and reduce the carbon footprint. ENGIE Lab CRIGEN develops simulation-based digital twins for industrial combustion plants to solve complex problems through advanced numerical simulations, which have long calculation times. Thanks to reduced-order modeling (ROM), which enables combining a CFD model with Ansys Twin Builder, these calculation times can be reduced considerably.

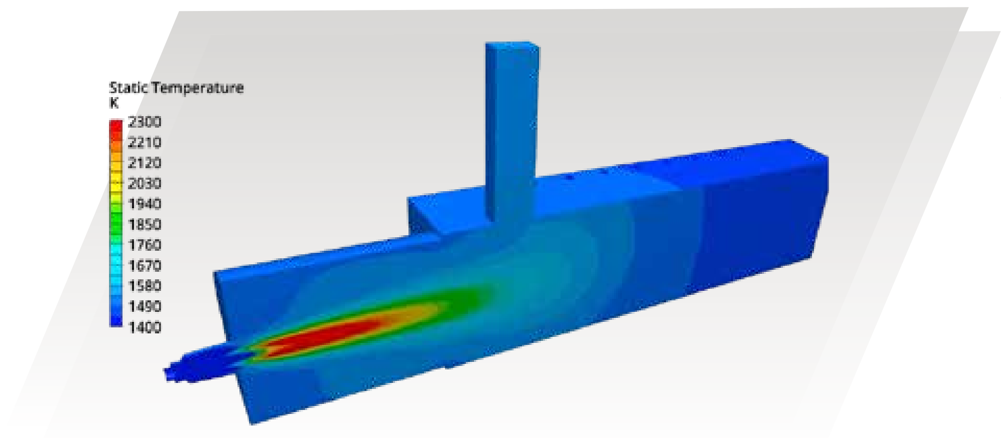
"The Ansys reduced-order modeling approach allows us to go from simulation times of several hours, or even days, to a few seconds," says Meynet. "The use of digital twins, and in particular ROM technology, completely changes the way digital simulation is used."

The ROM allows ENGIE Lab CRIGEN engineers to explore the modeled equipment in a much more advanced and precise way. They can study the impact of different physical parameters in real time and optimize the operation of the equipment by feeding the numerical simulation with data from the physical equipment. Once connected to the real asset, the ROM then becomes a digital twin, which can be used to perform predictive maintenance, capitalize on operating data or analyze a multitude of scenarios — all in a couple of seconds.

"This real-time technology allows us to observe and predict the behavior of our installation, and thus test strategies for the operation of the equipment by implementing, testing, and validating different scenarios instantly on the digital twin before deployment on the equipment," adds Meynet. "The customer can better understand, anticipate, and validate the proper functioning of his installation by virtually testing the changes on the equipment."

MAKING THE INVISIBLE VISIBLE WITH SIMULATION

Before the use of digital twins, manufacturers and onsite technical experts tested their physical equipment without being able to visualize what was going on inside the equipment. For example, in an industrial furnace when the power or fuel was modified, the experts could not visualize or predict the impact on the flame length, the combustion quality, or the heat transfer efficiency to the load. All this is now possible thanks to ROM and simulation-based digital twins.



With Ansys Twin Builder, ENGIE Lab CRIGEN has created a digital twin of an industrial furnace.

> ***"Thanks to the digital twin, our customers will be able to test different scenarios on their future equipment in the design phase and optimize their equipment, all this virtually and without a physical prototype."***
>
> **— NICOLAS MEYNET,** Multiphysics Simulation Expert, ENGIE LabCRIGEN

"Using Ansys' digital twin technology allows us to optimize performance and make the invisible visible, in real time," says Meynet.

ANSYS TWIN BUILDER: A KEY TECHNOLOGY IN ENGIE LAB CRIGEN'S INNOVATION

ENGIE Lab CRIGEN's R&D experts have succeeded in developing the first technology stack of their industrial digital twin with an industrial furnace, thanks to Ansys Twin Builder.

Before using Twin Builder, ENGIE Lab CRIGEN had an experimental industrial furnace equipped with numerous physical sensors connected by wire. With Twin Builder, they have a digital twin of the industrial furnace, complete with virtual sensors that collect detailed data from the heart of the equipment to ensure it is functioning properly and enabling them to anticipate possible failures via predictive maintenance.

The digital twin is currently connected to an industrial internet of things (IIoT) platform, which allows the physical separation of the industrial equipment from the digital twin. Ansys Twin Builder Runtime technology will enable better performance, ease of use, and more efficient maintenance.

"The deployment of the digital twin via an IIoT platform is a major step forward," Meynet says. "In particular, this should enable remote maintenance of the physical industrial equipment."

DIGITAL TWINS TO ANTICIPATE AND MINIMIZE ENERGY CONSUMPTION

The use of Ansys digital twin technology enables real-time optimization of energy and environmental performance of equipment: a key asset in the zero-carbon transition for Engie's customers.

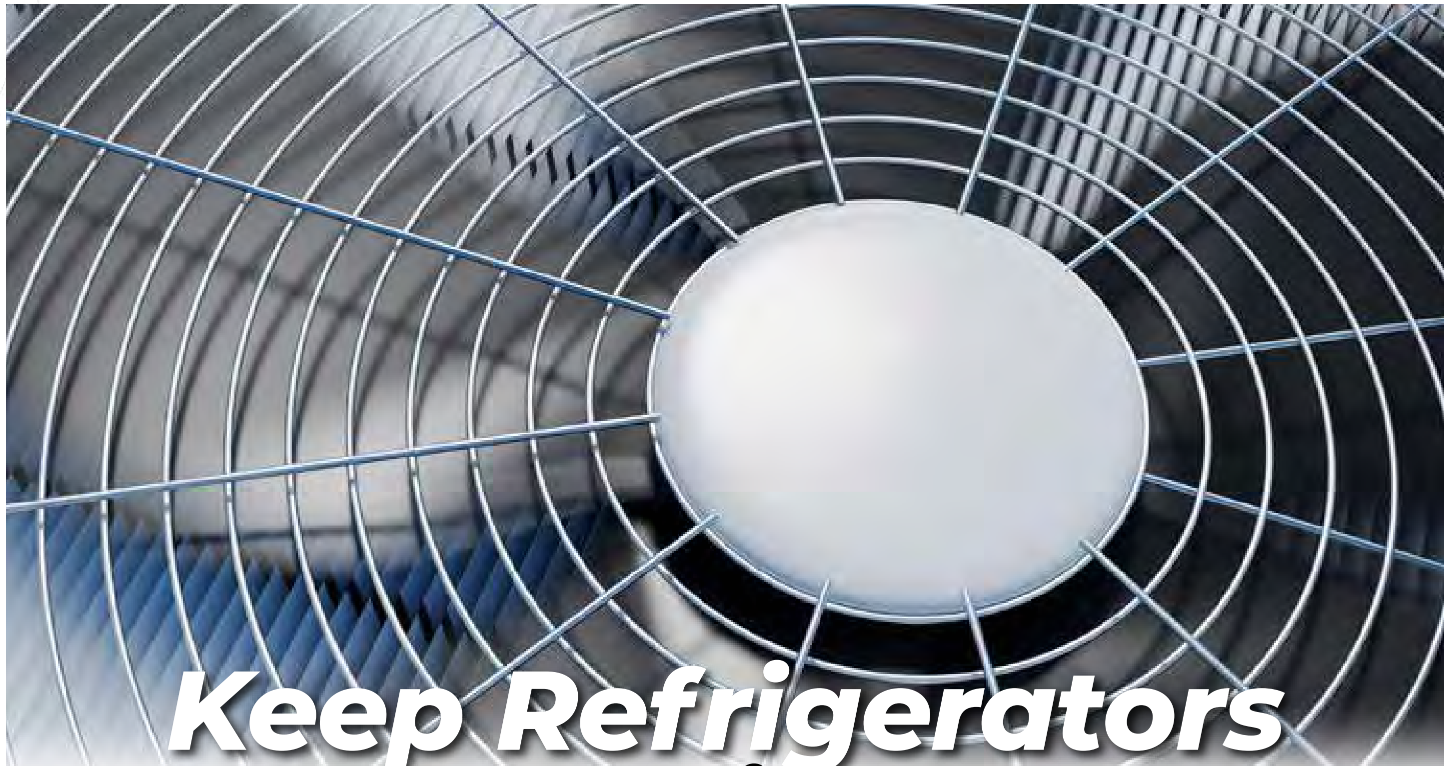
The other major benefit of using digital twin technology is to be able to anticipate the aging of physical equipment to improve its performance and thus considerably reduce maintenance costs.

The GRHYD project in Cappelle la Grande, France, tests the injection of hydrogen into the region's natural gas distribution grid to meet residents' energy needs.

"Digital twins facilitate the evolution of industrial equipment," says Meynet. "If we take the example of equipment that has been running on natural gas for years, thanks to digital twin technology, we can test and predict the behavior of the equipment with the addition of hydrogen, and thus facilitate this energy change on the existing industrial equipment thanks to simulation."

Ansys' digital twin technology also enables Engie to support its customers in the development phase of their industrial equipment, reducing the costs associated with physical prototypes.

"Thanks to the digital twin, our customers will be able to test different scenarios on their future equipment in the design phase and optimize their equipment, all this virtually and without a physical prototype," says Meynet. "Our customers will be able to test, optimize, and validate the design of their equipment virtually before production." /\



Keep Refrigerators Cool With Less Global Warming

By **Jennifer Procario**, Staff Writer, Ansys Advantage

With global warming and climate concerns impacting many industries around the world, the mere mention of carbon dioxide (CO_2) can trigger a negative reaction. In most cases, it's part of a discussion on ways to reduce or eliminate CO_2 emissions. However, although CO_2 contributes to rising temperatures, it isn't as potent as other greenhouse gases (GHGs) such as hydrofluorocarbons (HFCs), which are used in a variety of appliances, including refrigerators and air conditioning systems. In these applications, CO_2 actually presents a favorable alternative as a refrigerant when used in place of HFCs.

Ironically, HFCs, which are categorized as fluorinated gases, have been used as an alternative to harsher substances such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), which deplete the ozone layer and are being phased out under an international agreement called the Montreal Protocol. But while HFCs cause less damage to the ozone than the previous generation of refrigerants, HFCs have global warming potentials (GWPs) that typically range from the thousands to tens of thousands[1] and trap considerably more heat than CO_2 for a given amount of mass. Still, replacing HFCs with CO_2 in refrigeration has not been an easy or practical alternative for most manufacturers. For starters, CO_2 refrigeration systems require high pressure, which increases energy consumption and operational costs. Further, CO_2 refrigeration systems are not as energy-efficient in warmer climates (90 °F/32 °C and above).

To make CO_2 alternatives more affordable and efficient in all climates, Energy Recovery, Inc. (ERII) designed a new technology that it says

"Once I showed the coupled-physics CFD results, people slowly gained confidence in this concept and our board approved funds to build the first prototype and experimental setup to prove the concept experimentally. Ansys simulations enabled us to build high-fidelity models that played a very crucial role in investigating the multiphysics interactions that happen inside the rotor of the pressure exchanger and to validate the initial concept."

— **AZAM THATTE**, Ph.D., Chief Scientist, Energy Recovery, Inc.

democratizes CO_2 refrigeration. By integrating its own physics into Ansys' open simulation ecosystem to extensively model and analyze complex fluid flows, structural mechanics, and heat transfer, ERII developed the first-of-its-kind transcritical rotary pressure exchanger built exclusively for CO_2 systems. It recovers the expansion energy in the refrigeration system that would have otherwise been lost. This development is said to drastically reduce energy consumption and operational costs. ERII says the PX G1300 (PXG) provides energy-saving solutions for high-pressure CO_2 systems that contribute less to global warming than traditional refrigeration systems. The rotary gas pressure exchanger can be used in commercial and industrial refrigeration and cold storage, and in the future could be used for data center cooling, heat pumps, geothermal power generation, and renewable energy storage.

TRANSFORMING REFRIGERATION WITH CO_2 PRESSURE EXCHANGE

Since 1992, ERII has developed pressure exchangers that drastically reduce energy consumption and the operational costs of seawater reverse osmosis (SWRO), a process for water desalination. Expanding upon this area, ERII developed a pressure exchanger specifically for CO_2 refrigeration systems that it says solves the key challenge associated with low-global-warming CO_2 refrigeration and makes it a viable solution for a large part of the world.

The PXG is a rotary gas pressure exchanger for direct-contact, gas-to-gas, liquid-to-gas, and supercritical fluid-to-gas pressure exchange that is designed to significantly improve energy efficiency, which is defined by the coefficient of performance (COP). Additionally, the PXG provides both expansion and compression. ERII says the PXG recovers more than 95% of lost pressure energy in both subcritical and transcritical CO_2 refrigeration systems, i.e., systems that operate below and above the critical point of CO_2, respectively. The compressor discharge pressure is lower than the critical pressure in subcritical CO_2 systems, meaning the refrigerant can be condensed after rejecting heat to the ambient environment. Conversely, in transcritical systems, the compressor discharge pressure is greater than the critical pressure of CO_2 and there is no phase change in such a supercritical state. For this reason, the refrigerant CO_2 does not condense into liquid after rejecting heat to the ambient air. The PX G1300 seamlessly integrates with either system.

The PXG is the brainchild of Azam Thatte, Ph.D., the Chief Scientist at Energy Recovery, Inc., who was previously a research scholar at the Massachusetts Institute of Technology (MIT). Thatte first conceived and published the idea of achieving transcritical compression using expansion work recovery in a rotary gas pressure exchanger. Using first principles of thermodynamics and gas dynamics, he proposed that such a compression can be achieved without using any external mechanical or electrical energy. He suggested, instead, that the compression could be achieved through acoustic waves generated during direct-contact, fluid-to-fluid pressure exchange between the high-pressure supercritical state of fluid and the low-pressure gaseous state inside a rotary pressure exchanger. However, to prove this hypothesis, he needed to build high-fidelity, multiscale, multiphysics models to study the intricate physics of this challenging problem. Further, he needed to couple the 3D macroscale gas dynamics, species and thermal transport, and wave propagation with 2D microscale, thin-film fluid physics — which also have extremely fine spatiotemporal resolution — to capture the ultra-fast timescales and geometrical nuances of the problem.

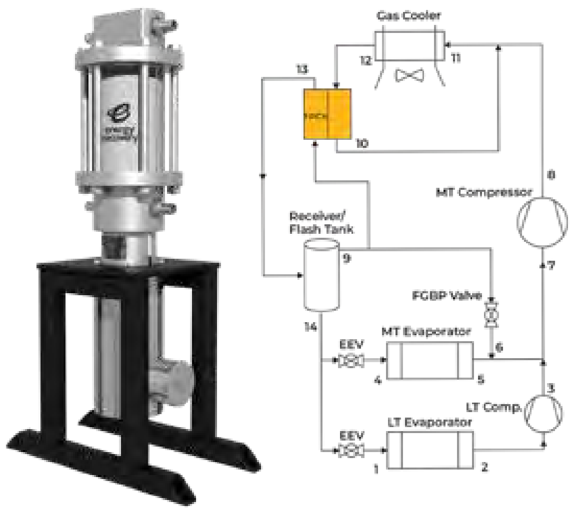


Figure 1. Energy Recovery, Inc. developed the PX G1300, a unique rotary gas pressure exchanger, to enable energy-saving solutions for high-pressure, transcritical carbon dioxide (CO_2) refrigeration systems.

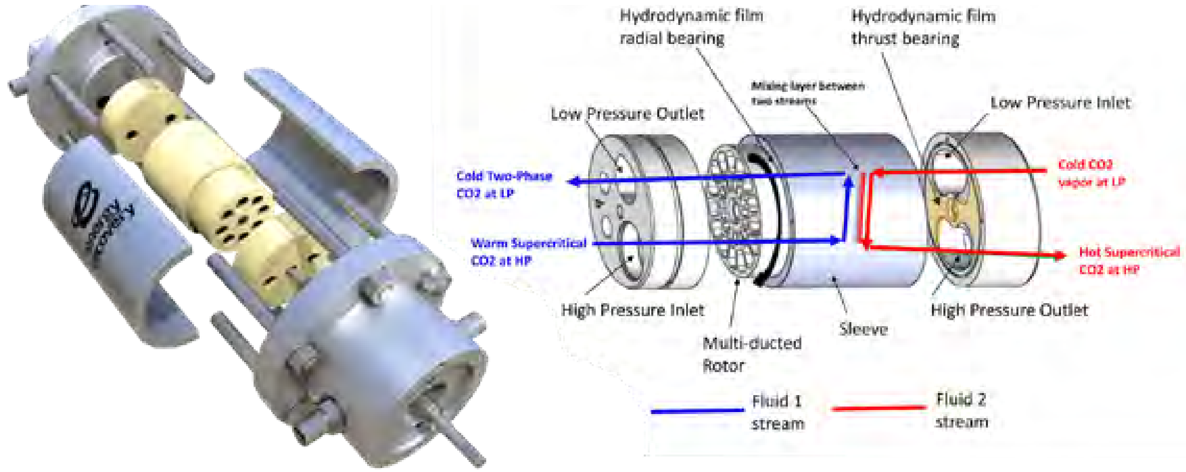


Figure 2. The PX G1300 rotary gas pressure exchanger functions as both a compressor and an expansion device, so it can significantly reduce energy consumption and operational costs in CO_2 refrigeration systems. The pressure exchange within the PX G1300 device completes in six main steps during one complete rotation then repeats in a continuous process thousands of times a minute.

This is when Thatte shifted ERII's research and development process from an empirical-research focus to a multiphysics-prediction-assisted methodology using Ansys simulation software.

Combined with his own set of partial differential equations, the computational fluid dynamics (CFD) capabilities within Ansys CFX enabled Thatte to explore the nonequilibrium thermodynamics that occur in the supercritical state of matter. In addition, he was able to observe the interaction between multiple phases of fluid (gas, liquid, liquid–gas mixture, and supercritical state of CO_2), fluid–structure interaction, thermal transport, and species transport, which all happen simultaneously inside the transcritical rotary pressure exchanger. Furthermore, he was able to capture large variations in length scales from microscale to macroscale and timescales from microseconds to a few hundred seconds. This exploration and research led to the development of the PX G1300 technology.

Thatte says the compression of low-pressure gas (Fluid 1 in Figure 2) achieved in PXG is "free compression," which does not consume any external mechanical or electrical energy, unlike traditional compressors. It is purely facilitated by the enthalpy extracted during the expansion of high-pressure fluid (Fluid 2 in Figure 2). According to Thatte, PXG can compress up to 30% of the total refrigerant mass flow using this free compression and therefore reduces energy consumption of the system by up to 30%. Additionally, because enthalpy is extracted during the expansion process inside PXG, it produces more liquid than the liquid produced during isenthalpic expansion across the expansion valve of a traditional refrigeration system. Also, because it is this cold liquid that produces refrigeration, additional cold liquid produced by PXG per unit mass flow further reduces energy consumption of the system.

PROVING CORE PHYSICS AND PXG TECHNOLOGY WITH SIMULATION

Within the PXG, a multiducted rotor spins at very high speed, enabling a continuous and simultaneous compression and expansion through acoustic waves generated during pressure exchange between high-pressure, supercritical CO_2 and low-pressure, gaseous CO_2. Compression and expansion waves propagate back and forth at the speed of sound through the ducts — a discovery Thatte says he made

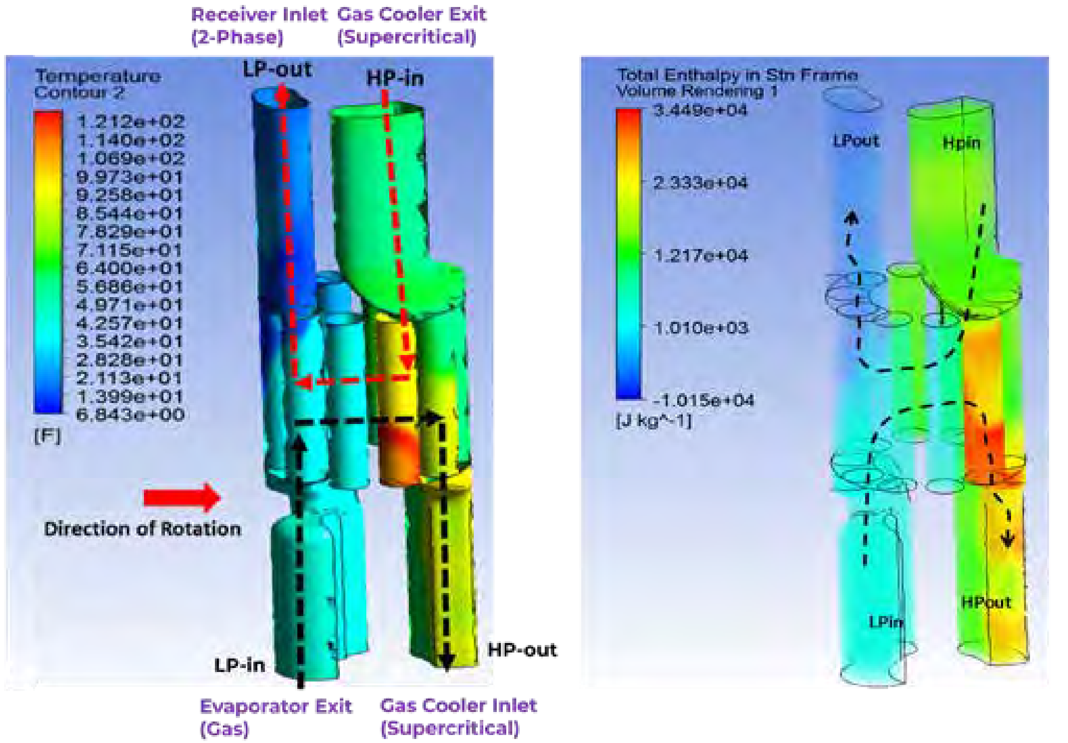


Figure 3. This Ansys CFX simulation illustrates the "free compression" achieved through acoustic waves generated during direct-contact, fluid-to-fluid pressure exchange within PXG (right) and the temperature distribution (left).

and proved through coupled-physics simulations and analyses.

"Nobody was willing to believe this hypothesis because it was such a radical idea of using a supercritical state of matter to compress low-pressure gas through acoustic waves generated during direct-contact, fluid-to-fluid pressure exchange," he says. "People could not believe it until I showed them the high-fidelity 3D Ansys simulation and explained to them that this is actually solving three-dimensional Navier-Stokes equations, the thermal transport, species transport, and phase change all at once."

Traditionally, a reciprocating compressor has a piston that compresses the gas, trapping it between a stationary wall and a moving piston and that's how the pressure is increased. On the other hand, a centrifugal compressor has blades that spin at high speed and convert kinetic energy into pressure energy.

THE SCOPE OF ENERGY RECOVERY'S NOVEL PXG TECHNOLOGY

ERII's PX G1300 could disrupt the field of refrigeration and offers an opportunity to facilitate massive energy savings and reduce carbon footprints on a global scale by making it easier to implement CO_2 as a natural low-global-warming, nonflammable refrigerant, which is also nontoxic and doesn't deplete the ozone layer. Due to the significant impact made by PX G1300 in the refrigeration field, it recently won the "Refrigeration Innovation of the Year" award at the Atmosphere America Summit 2023 in Washington, D.C.

ERII assessed potential electricity and cost savings in the U.S. and Europe, comparing a PXG-enabled CO_2 refrigeration system with a standard CO_2 refrigeration system. The company estimates that every 1,000 supermarkets in the U.S. deploying the PX G1300 would save approximately 67 GWh of electricity, lower costs by about $10 million, and reduce CO_2 emissions by around 16,000 metric tons — the equivalent of removing approximately 3,400 passenger vehicles from U.S. roads. For every 1,000 supermarkets in Europe, ERII estimates that deploying the technology would save approximately 43 GWh of electricity, lower costs by about €6.6 million, and reduce CO_2 emissions by around 9,600 metric tons — the equivalent of removing approximately 6,000 passenger vehicles from European roads.

Figure 4: An experimental setup was built to validate the predictions of PXG physics and the energy savings. Ont the left: the high-pressure gas cooler with supercritical CO_2. On the right: the low-pressure evaporator and receiver with two-phase and gaseous CO_2.

The PXG uses acoustic waves to create almost instantaneous pressure exchange at the speed of sound, eliminating in the process the energy loss that typically occurs with traditional technologies, says Thatte. Its name, PX G1300, is a nod to the first milestone pressure reached during its earliest demonstrations at 1,300 psi.

"Once I showed the coupled-physics CFD results, people slowly gained confidence in this concept and our board approved funds to build the first prototype and experimental setup to prove the concept experimentally," explains Thatte. "Ansys simulations enabled us to build high-fidelity models that played a very crucial role in investigating the multiphysics interactions that happen inside the rotor of the pressure exchanger and to validate the initial concept."

Figure 4 shows the experimental setup that ERII built to validate PXG's transcritical CO_2 compression-expansion physics and its energy savings in the CO_2 refrigeration system. By integrating PX G1300 into a CO_2 refrigeration system, ERII says it has demonstrated experimentally up to 30% improvement in COP for warmer climates and more than 20% COP improvement for relatively cooler climates.

In addition to the fluids analyses, Thatte evaluated the structural integrity of the device using Ansys Mechanical. Through thermal analyses, Thatte ensured that the PXG's rotor ducts could withstand high-temperature thermal stresses and that the thermal expansion would not excessively close the microscale hydrodynamic bearing clearances between rotor and stator. He also confirmed that its gas-film bearing stiffness would prevent contact between the rotor and stator, allowing the rotor to spin freely during the pressure exchange process.

Thermal analyses also helped ERII select and validate the ceramic core material of the device, together with Ansys Granta MI Enterprise materials data management software. Within Granta, Thatte explored a wide variety of materials and their thermophysical properties. Additionally, Ansys high-performance computing (HPC) solutions enabled Thatte to run complex, computationally intensive simulations on a supercomputing cluster that he has designed and built at ERII. Thatte also credits the support from Ansys Elite Channel Partner Ozen Engineering, Inc. in navigating the complexities associated with running such coupled physics models on supercomputing clusters.

Thatte says Ansys simulation tools significantly accelerated the timeline from initial discovery and concept exploration to technology maturation and product commercialization.

"Design methodologies are not only to understand what's happening at the fundamental scientific level, but also to mature the technology from the ideation and conceptualization stage all the way to commercialization in a very fast-paced manner," he says. "Ansys was very helpful from the early conceptualization stage of the PXG. From when I first came up with the idea to actually installing this product in a commercial setting in an Italian supermarket — and saving close to 30% of the energy for that customer — all happened within a span of just over two years, and that was in large part due to the insights I gained from the multiscale, coupled-physics Ansys simulations."

Having successfully demonstrated energy savings provided by PXG technology, Thatte is now exploring novel applications of PXG for increasing energy efficiency of heat pumps, data center cooling, geothermal power generation, and thermal energy storage.

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Going with the Flow:

Ansys Helps Wärtsilä Energy Powershift Toward a Sustainable Future

By **Laura Carter**, Senior Corporate Communications Writer, Ansys

Renewable energy production depends on cooperation from the environment. There are natural forces at play with wind, solar, and hydropower delivery. But what happens when the sun stops shining, the wind stops blowing, or the water stops flowing? The answer rests with the energy that's left behind. Not all of the renewable energy produced from renewable sources is needed or used the moment it is harvested.

So, where does all this excess energy go? In the case of solar, wind, or hydropower, given ever-changing environment dynamics, the output is clearly not consistent enough and risks energy loss. Powershifting is needed to maintain a steady stream of energy to the grid. With the help of an integrated energy storage system, any downtime in energy production can be compensated for in the banking of excess output collected during peak periods of energy harvesting that would otherwise go unused. Ansys solutions enable Wärtsilä, Energy, a leader in the transition to a 100% renewable energy future, to simulate and build GridSolv Quantum — optimized by their GEMS Digital Energy Platform — a fully integrated, shelf-ready storage system. It has a 20-year design life and delivers high energy efficiency to help keep the power flowing.

DESIGNED WITH SUSTAINABLE ENERGY OPTIMIZATION IN MIND

Wärtsilä, headquartered in Helsinki, Finland, develops market-leading technologies and life cycle solutions for the marine and energy markets. They specifically designed their fully integrated energy storage system for ease of deployment and sustainable energy optimization for use across solar, wind farm, and power plant applications. Components are pre-assembled and shipped to the customer site. Each energy storage unit consists of hardware such as battery cells, cooling and fire suppression systems, and inverters or power conditioners, plus the software needed to regulate them. Excess energy is captured and stored for future use within the system using lithium-ion batteries.

Customers interested in energy storage systems are generally focused on stability and reliability, including actual operation costs, the rate of battery charge and discharge, and their susceptibility to degradation — all of which can be answered using simulation software. Designing an entirely new energy storage system to meet these expectations requires a complex system model that can simulate and capture the thermoelectric and electrochemical behavior of the battery, along with the complicated transient heat transfer between

Wärtsilä GEMS Digital Energy Platform
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Wärtsilä's GridSolv Quantum is a fully integrated, modular, scalable energy storage solution.
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"With the help of Ansys simulation software, we were able to layer and build an accurate representation of our system that we can use to understand thermal management performance. Simulation also saved the team six months of development time and reduced the number of physical prototypes by three."

— **DEWEI GUAN**, Product Development Engineer at Wärtsilä

multiple system components. The model must accurately predict battery module temperature change in transient analysis — the calculation of a circuit's response over a defined time period. Successful simulation depends on seamless data exchange between the system model and a unique software environment.

To build a system model to meet their objectives, Wärtsilä set out to accomplish a number of goals using simulation, including:

- Looking to battery performance data to build a battery cell model based on an electric circuit model (ECM).
- Creating a chiller model to determine power consumption and cooling capacity based on battery and coolant temperature.
- Generating and validating a reduced-order model (ROM) from a computational fluid dynamics (CFD) model of the cold plate to align system accuracy and computational speed.
- Combining ECM and ROMs into a battery module to understand state of charge as a function of various factors, and to control battery charge and discharge rates.
- Combining model components to create an accurate battery storage system model for testing and validation.

"As an engineer, you always question what the system margins are to boost customer confidence," says Dewei Guan, Product Development Engineer at Wärtsilä. "All these questions you're not able to solve with a hand calculation or a simple model — you have to couple these multiphysics problems together with the system model. We have to use multiphysics simulation software to answer these questions and solve very specific problems for our customers."

TAKING CHARGE OF SYSTEM PERFORMANCE WITH SIMULATION

Simulation enables the team to deliver an accurate, reliable model of the storage system that can test and validate the overall system performance over the life of the battery. Ansys solutions help Wärtsilä easily predict what is going to happen over the next five years. The simulation software provides intuitive, user-friendly tools that address system development and validation from every perspective. Wärtsilä used Ansys' comprehensive set of solvers at every stage during validation of their storage system, whether working at the system level or capturing a specific electrical response.

Ansys Twin Builder's ROM technology also enabled a significant reduction in overall simulation time — from one day to 10 minutes with a high-fidelity representation of the CFD model, resulting in faster product development.

"We do everything inside Ansys because Ansys basically has a tool for every engineering perspective," says Guan. "For instance, Ansys SpaceClaim is a very user-friendly, intuitive way to create our basic model. We can then transfer this CFD model of the results from Ansys Fluent to Twin Builder to understand the thermal performance of our model. Following this workflow, we can simulate a system-level response quickly and easily."

SPINNING AT THE SAME FREQUENCY

Beyond interruptions in power flow, there are frequency regulation use cases — cases where the system frequency gets too high or low that can be addressed with Wärtsilä's energy storage system. For a power plant to operate, every generator must be spinning at the same frequency to maintain overall system stability; however, it's often difficult for facilities to deliver their system response as fast as the demand change. If the supply is larger than the demand, the frequency will rise above 60 Hertz. If it is lower, it will dip below 60 Hertz.

Let's say a power plant consistently outputs 100 megawatts of energy, but sometimes demand is 120 megawatts. When the demand is higher, the frequency will drop because the rotor in the power plant will not be able to rotate as fast as required, creating unstable conditions. Wärtsilä's storage system is in the middle of this transaction to balance the difference between the power plant's output and increased demand. The energy storage system responds to any differences between power generation and the demand change by either absorbing extra power via the batteries or, in this case, delivering stored power from the batteries so the frequency will remain constant.

In this scenario, successful powershifting depends on Wärtsilä's storage system's ability to act as an intermediary in the flow of power delivered to the grid. Guan relies on simulation data to do cell-level testing to understand the degradation of the battery cell, collect data, and then input it to predict module- or system-level behavior, or to improve on storage system design. Using surface simulation during piping development, for example, Guan and team could accelerate a new piping design, which requires an evenly distributed flow to each battery module. In this instance, Fluent enabled the accurate pressure drop and flow rate prediction needed to ensure the appropriate energy flow. Ultimately this testing required just one prototype, saving six months of development time and resulting in a significant cost savings.

"Wärtsilä uses Ansys software for complex battery storage system modeling to accurately test the life expectancy of our energy storage systems," says Guan. "With the help of Ansys simulation software, we were able to layer and build an accurate representation of our system that we can use to understand thermal management performance. Simulation also saved the team six months of development time and reduced the number of physical prototypes by three."

It's benefits like these that drive Guan's reliance on Ansys simulation software during development, which enables quick, easy system modeling, as well as simulation of an accurate system-level response.

4 Ways to Increase Safety and Security of Battery Management Systems

By **Mazen El Hout**, Senior Product Marketing Manager, Ansys

The world is going electric. Cars, aircraft, industrial processes, energy storage, you name it: Industry is making a major shift toward electrification, and with that comes an ever-growing demand for more batteries. But transitioning to a lower-carbon future doesn't mean people or companies are ready to compromise on efficiency; they expect at least similar — or superior — performance from electric batteries. Delivering this can prove to be quite complex. In vehicles, for instance, batteries have to be powerful enough to control an electric motor, cabin climate, several infotainment systems, and more.

To achieve this, batteries need to charge efficiently, store energy effectively, and operate safely, delivering reliable performance over years of usage. But smart batteries are complex systems that require an embedded control unit: the battery management system (BMS).

The BMS is the brain of electric power systems. It continuously monitors conditions, redistributes energy resources, and sends alerts in the event of a problem. This whole system must operate optimally to ensure safe and efficient energy usage.

The BMS includes embedded software for real-time monitoring and control of rechargeable batteries to provide reliable power, even in complex applications. They control many elements such as voltage, current, and temperature to balance the charge between cells, protect from overvoltage, and ensure safe operation despite repetitive charging and discharging cycles.

Today, many of the engineering challenges surrounding the electrical revolution center on the electric battery and its management system. Let's take a look at four ways you can use simulation to design a BMS that meets the major challenges of efficiency, safety, and reliability.

1 OPTIMIZE BATTERY DESIGN WITH MULTIPHYSICS SIMULATION

Battery engineers and designers are constantly exploring materials that will be more energy efficient and less prone to overheating and burning. Controlling the temperature of batteries is essential to prevent them from becoming too hot and, catastrophically, catching on fire. Despite each material having unique properties, Ansys multiphysics solutions enable you to thoroughly model a battery system. Multiphysics coupling gives engineers a complete picture of the structural, thermal, and electrochemical response of a battery.

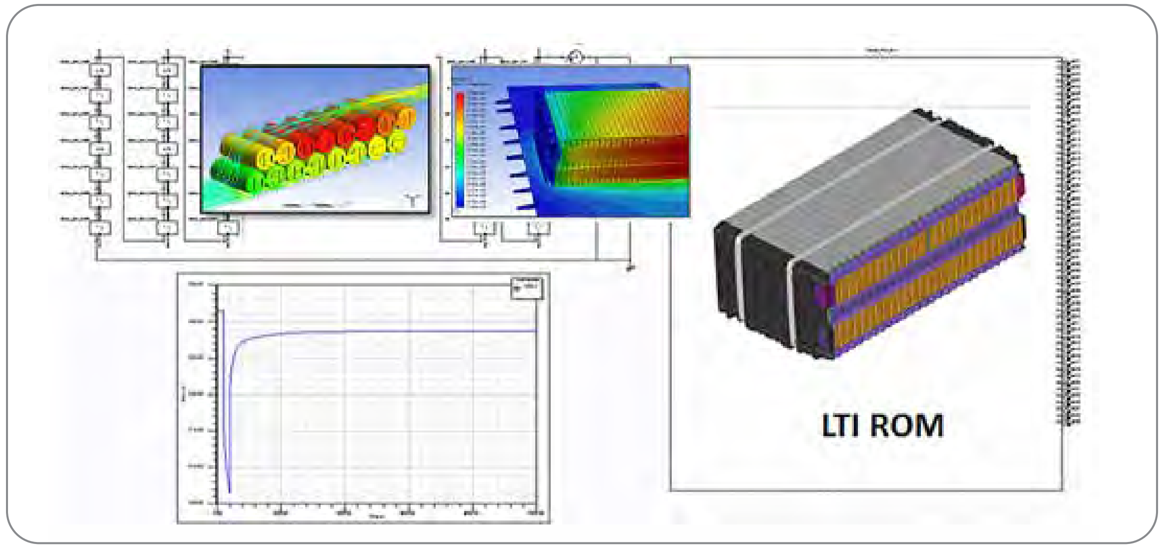
Ansys Fluent is used for cell design, thermal management, and thermal runaway, helping engineers design batteries that will be resistant to thermal abuse.

Ansys Mechanical is used for modeling structural stresses and strains produced by differential heating and cooling. It tracks the effects of temperature on the structure to ensure that the battery's components can withstand any thermal-induced stresses. It also simulates structural failure in these conditions and determines whether a new design will prevent failure.

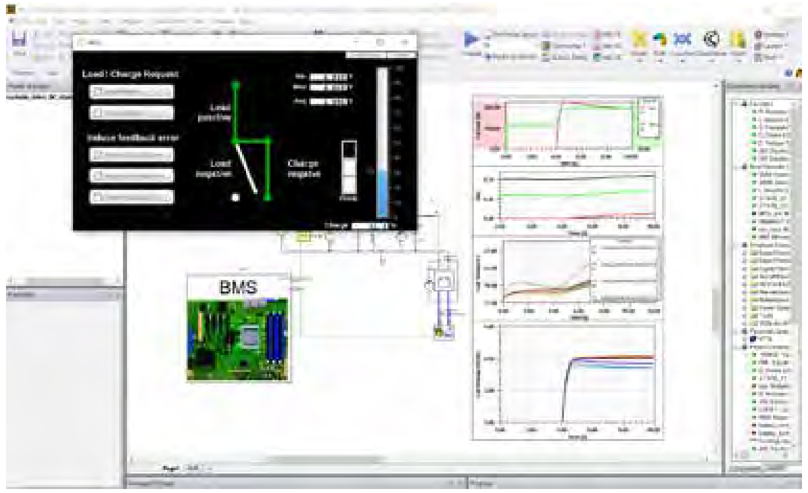
2 PERFORM SYSTEM-LEVEL MODELING USING DIGITAL TWINS

Following multiphysics coupling, when all the components of a battery system are ready to be connected, you can gain an accurate perspective on how the BMS and battery will perform throughout their entire life cycle using a digital twin. Ansys Twin Builder accounts for all physical changes during a battery's design, manufacturing, and operating life cycle. It simulates how they will work together to achieve optimal efficiency.

However, optimally designed components do not necessarily result in optimal systems. When these components are powered, sensed, and controlled together as an integrated system, they might perform differently than when they were tested as standalone components. Twin Builder can perform closed-loop testing that encompasses the entire connected system to detect any component



High-fidelity thermal and structural analysis for a battery module using Ansys multiphysics solvers



System simulation integrating thermal and electric models and BMS software-in-the-loop

weaknesses and correct them to produce a battery system that operates at maximum efficiency.

3 ENSURE THE SAFETY OF BMS DESIGN WITH SYSTEM ARCHITECTURE

Ensuring the functional safety of a BMS is of the utmost importance, but it is not an easy task. To perform key functional safety analyses across many industries, especially the automotive sector, one integrated tool enables you to perform efficient and consistent execution of safety-related activities.

Ansys medini analyze performs key safety analysis procedures as specified by different standards in different industries, along with diagnostic and failure mode and effects (FMEA) analysis. For automotive systems, it checks that the BMS software satisfies the functional safety standard ISO 26262, starting with the identification and description of functions and malfunctions of the BMS.

Once malfunctions have been identified, a hazard and risk analysis is performed to identify the hazardous events and their impact on safety by determining the automotive safety integrity level and corresponding safety goals and safety requirements.

4 AUTOMATICALLY GENERATE EMBEDDED CODE FOR BATTERY MANAGEMENT SOFTWARE RELIABILITY

Because battery systems combine hardware and software, development teams have traditionally worked separately. Today, Ansys is changing that paradigm with an integrated simulation platform for battery design and BMS development.

The embedded software in the BMS can be generated and verified automatically using Ansys SCADE Suite. The SCADE product line provides a model-based development environment for critical embedded software at the application level, deployed in electronic control units of different automotive systems with optimized code quality and development costs. Using a software controller, engineers can intelligently monitor a battery's operating conditions and oversee its safe operations. Using Ansys SCADE's end-to-end model-based development solution can eliminate the need for costly code reviews and low- level testing.

Many stakeholders from different engineering areas can easily understand the model-based software and review the model's functionality. The solution is compliant with architecture standards such as AUTOSAR and ASPICE, and the automatically generated code is compliant with safety certification standard ISO 26262.

"With SCADE, many things have become faster. The improvements in our largest unit, which is responsible for diagnosing the battery management system, have been dramatic. Overall we have become significantly faster in terms of testing, not only in terms of pure testing, but also for coverage analyses due to the elimination of code analyses," says Dr. Daniel Kirschner, head of Tools & Methods/ Battery Management System at Volkswagen.

SIMULATE THE BATTERY DEVELOPMENT PROCESS

Simulation helps engineers design BMS throughout the development process. The combination of Ansys' simulation capabilities mentioned above is essential for rapid virtual prototyping of a BMS, as more and more systems will rely on battery power in the future. The main benefits of model-based development are the ability to have reference models, reuse them across different development phases, and reduce the effort and risks of the transitions between design phases. Ansys solutions for embedded software and functional analysis enable BMS development for secure, safe, and efficient battery operation.

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