EUROPEAN ENERGY INNOVATION
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On thin ice

Energy policy, scientific cooperation and the end of Arctic exceptionalism

TECHEM on decarbonising heating with data and low-temperature systems

Presentations by energy research projects including **HiPE, NICHOLy** and **SCARLET**

Happy Birthday EEI: celebrating 15 years of communicating innovation

European Commission

9–11 JUNE 2026

EUROPEAN SUSTAINABLE ENERGY WEEK

A clean, secure and competitive Energy Union

20 YEARS

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ec.europa.eu/eusew

TAKE PART IN THE BIGGEST CLEAN ENERGY EVENT IN EUROPE

Not only is the European Sustainable Energy Week (EUSEW) the biggest annual event dedicated to clean energy in Europe, but also a landmark one: this *coming edition marks its 20-year milestone*. Under the theme 'A clean, secure and competitive Energy Union', EUSEW will be held from 9-11 June 2026 in Brussels and online. With a Policy Conference, Awards Ceremony, Energy Fair, European Youth Energy Day and Sustainable Energy Days, there are plenty of ways to join in and put your work in the spotlight. In the run up to the event, EUSEW offers year-round opportunities for the energy community to engage, connect and contribute to Europe's clean energy transition.

JOIN THE PROGRAMME AS A HOST

Through its largely co-created programme, the EUSEW Policy Conference gathers contributions from industry representatives, researchers, policymakers, EU project partners, entrepreneurs and civil society to exchange knowledge and ideas. Each year, more than 60 sessions are held on key energy topics and the role of EU energy policy in shaping a clean, secure, resilient and affordable energy system. Join the programme by submitting *your policy session proposal* by 22 January 2026.

LEAVE YOUR MARK WITH THE EUSEW AWARDS

This year, EUSEW Awards will celebrate winners in three categories: Local Energy Action, Women in Energy, and for the first time – SMEs Driving Energy Efficiency. Until 29 January 2026, you have the opportunity to apply as a candidate and put your project or initiative in the spotlight, or nominate someone else. Once a high-level jury announces the finalists, you can also take part in the *online public vote* from 5 May 2026 and help decide who wins the Awards. No matter the outcome, all EUSEW Awards finalists gain strong visibility through a promotional video, press package, and participation in the Awards Ceremony on 9 June 2026 in Brussels.

EXHIBIT YOUR WORK AT THE ENERGY FAIR

Host a stand at the Energy Fair in Brussels or come by during the Policy Conference to meet in person other professionals advancing clean energy and climate targets. Each year, the Fair is *buzzing with conversations* – this is where you can connect, learn about others' projects and gain the latest insights into the energy sector. Applications to host a stand open in January 2026.

YOUTH VOICES STEERING THE ENERGY TRANSITION

European Youth Energy Day, held during the EUSEW 2026, is a platform dedicated to young professionals aged 18-35 who are committed to shaping Europe's energy future. At its core, is the EUSEW Young Energy Ambassadors initiative with dozens of outstanding professionals contributing their experience and perspectives. The open call to join the new cohort will launch in January 2026.

EARN THE TITLE OF A SUSTAINABLE ENERGY DAY

All over Europe and beyond, locally hosted clean energy events are put on the map as EUSEW Sustainable Energy Days. These diverse community events are held between March and June 2026. You will be able to apply for this prestigious title from mid-February, gaining visibility through the vast EUSEW community.

EUROPEAN SUSTAINABLE ENERGY WEEK 2026

Organised by the European Commission, the European Sustainable Energy Week (EUSEW) is the biggest annual event dedicated to renewables and efficient energy use in Europe. Whether you are shaping policy, showcasing solutions, supporting local initiatives or amplifying youth voices, EUSEW offers numerous ways to get involved and help drive Europe's clean energy transition forward. Don't miss the calls to contribute to this year's programme and mark your calendar to reserve your seat at the event: registrations to attend open in April 2026. For ongoing updates, visit ec.europa.eu/eusew and follow #EUSEW2026 on social media.

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Foreword

By **Ed Wiseman**, *EEI* editor

It is November 2025. I am writing this article in my cabin on the Stena Germanica, a methanol-fuelled ro-pax ferry serving the Gothenburg-Kiel route. I have spent the day in Sweden, testing the electric Zeekr 001 FR hatchback's 2-second 0-100kmh time. Outside my porthole, over the freezing Kattegat, is the 400MW Anholt offshore wind farm, the flashing beacons of its 111 turbines piercing an obsidian sky.

Fifteen years ago, when the first edition of *European Energy Innovation* went to press, these were all plans for Europe's near future. DONG Energy had been granted a licence for the Anholt installation but had yet to begin work, EVs were a nerdy novelty for early adopters who could tolerate their limitations, and Stena Line was participating in methanol research projects but was still half a decade away from converting this ship from diesel-only operation.

Its participants may grumble about delays, but the green transition is characterised as much by pace and momentum as by frustrations and bottlenecks. As *European Energy Innovation* reaches 15 years of age, it is inspiring to recognise how many technologies have evolved and matured within that timeframe from hopeful ideas, to encouraging lab tests, to successful pilots, to real-world implementation and, ultimately, to boring aspects of modern European life. I might be the sole passenger on this ship giving those faraway lights a second thought, which shows how far we've come in a very short space of time.

A brief look back

The *EEI* team has asked its friends from around the energy sector for their reflections on the past 15 years, and you can read their answers on pages 12-16. Meanwhile, we've been flicking through our back catalogue of editions – which is available for free on our website, below – to join the dots between 2010 in European sustainability R&I, and the world we live in today.

As it happens, wind has been notable in its maturation. In the Winter 2010 edition of *EEI*, journalist Philip Hunt reports that "by 2030, average turbine sizes of 2MW (onshore) and 10MW (offshore) are expected, with gigawatt-size wind farms likely for offshore". In fact, the Siemens Gamesa turbines at Scotland's Moray West are rated at 14.7MW each, and while that particular wind farm falls short of the projected gigawatt at a mere 882MW, Hornsea One and Two stand at 1.2GW and 1.3GW, respectively. Siemens Gamesa is currently testing a 21.5MW turbine with a rotor diameter of 276m.

The same article mentions the then-nascent technologies of wooden towers and vertical axis turbines, both of which are now being deployed. It also includes a chart that shows total installed capacity rising from 24,322MW in 2021 to an estimated 203,500MW in 2010; we know from our vantage point in 2025 that this chart climbs dramatically on its way to the 1.3TW-ish figure we're approaching today. Analysts predict the next terrawatt will take one-third as long as the first one did.

Boring European life

"The growth in the use of electric cars has been far from spectacular," grumbles former editor Michael Edmund in the Summer 2011 edition of *EEI*, pointing out the 160km range and multi-hour charging speed of most early EVs. The year before, just 600 new electric cars had been sold in Europe, resulting in a market share of a fraction of a percent. But unbeknownst to the author, a quiet revolution had already begun, and European EV sales had begun an ascent that the word "spectacular" doesn't even begin to cover.

By the end of 2011, Europeans had bought around 7,000 new electric cars – a tenfold increase, and some, fuelled in part by the arrival of Nissan's Leaf, which I enthuse about on page 12. The following year, and for several years after that, the figure increased by around 60 percent. Within five years, mass-market electric cars earned a market share of over a percent, then reached 10 percent by 2020, and then 20 percent by 2022.

When *EEI* was founded, Europeans bought 600 EVs a year; today, they'll buy 600 EVs before lunchtime. Outside St Pancras or Bruxelles-Midi, I am as likely to find an electric taxi as I am a clattery old diesel one, an idea that felt almost space-age not long ago. It is remarkable how quickly these products have reached ubiquity.

An ongoing process

It's fair to point out that electric cars were invented a century ago, and that the past fifteen years represent their rapid evolution and popularisation, rather than their genesis. Like the first fish to squirm out of its Devonian ocean and onto dry land, the REVAi G-Wiz quadricycle (Britain's most popular EV, in 2009) was just a small, ungainly part in a much grander process that includes primitive turn-of-the-century motor-wagens to the 1,265PS hypercar I've been hoofing up and down a Swedish airstrip all afternoon.

The *Germanica* was the world's first methanol ro-pax ferry, and remains one of only a handful of ships that have been converted or, even rarer, to have been built to run on both fuels. Perhaps over the next 15 years this technology – or hydrogen lorries, or perovskite-tandem photovoltaic panels, or direct air capture, or gravity energy storage – will experience implementation booms just as EVs or offshore wind have since 2010. We always welcome readers' thoughts, so please do share your own predictions with the team using one of the emails on this page.

It's another particularly interesting issue this quarter, with brilliant submissions from expert writers across the green transition. In a few pages, Techem introduces its 2025 Atlas, with some insights into using consumption data and driving decarbonisation with heat pumps. The HiPE project explains its plans for wide-bandgap semiconductors in the automotive industry, the NICHOLy project talks about improving the storage of liquid hydrogen, and the SCARLET project discusses multi-gigawatt transmission using superconducting cables, which have important applications in various environments. And we have a unique glimpse into the darkened rooms of the European Solar Test Installation, written by Dr Christian Thiel, Head of the Energy Efficiency and Renewables Unit at the JRC.

In our aviation mini-dossier, we have technical presentations by Lufthansa, ONERA and Clean Aviation, while at the back of the magazine we have unique analysis by *EEI* writers Sam Meadows (on the political difficulties of lithium extraction) and Xiaoying You (who writes about the implications of India's PV push). We also have our event listings, a special birthday feature, and more.

Later tonight, while I am hopefully sound asleep, the first-ever methanol ferry will chunter past the site of the first-ever offshore wind farm, Vindeby, which was built in 1991 and recycled in 2017. It had a nameplate capacity of 5MW. It is fun to look at the innovations, pilot schemes and real-world implementations being built today, and wonder what we might think of them – and the mark that they by then will have left on the green transition – in the decades to come. ■

In this issue


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Europe's strategic choice

The next budget brings a chance to invest in the technologies and skills that will define the decade ahead – and Europe's competitiveness

By **Sabine Verheyen,**
First Vice-President of the European Parliament

Across Europe, energy shapes daily life and long-term prospects. Families rely on secure supply; industries – from steel to semiconductors – depend on stable energy supplies to remain competitive. The crises of recent years, from price shocks to geopolitical pressure, have revealed how vulnerable our system can be.

Our task is clear: ensure stability, reach climate goals, and strengthen Europe's industrial foundation. This is not a national endeavour but a European responsibility. Only together can we align environmental ambition with economic strength. The reform of the electricity-market design and the Clean Industrial Deal mark essential steps in that direction.

The Industrial Transition as a European Project

The move toward climate neutrality is no longer a goal for the future. It is already reshaping our economies, as ports are become hubs for offshore wind, industrial clusters develop hydrogen corridors, and companies adapt production to cut emissions while staying viable. This transformation defines Europe's place in global competition. The United States accelerates investment through its Inflation Reduction Act; China expands its dominance in solar and battery production. Europe must respond with its own strengths: a single market, a creative research landscape and a culture of reliability.

Citizens and businesses alike need to see that this transition is feasible and fair. Research and innovation turn that promise into practice.

EU-supported projects show the impact: cross-border hydrogen pilots, offshore wind driving local economies, storage technologies stabilising power systems. These are not isolated ventures but parts of a shared structure. European funding transforms prototypes into production and research into capacity. Without that bridge, we risk losing knowledge and industry abroad.

Yet innovation cannot be a patchwork of unconnected efforts. The energy transition must work as a system – where generation, storage, grids and consumption interact seamlessly. Expanding renewables without matching grid or storage capacity risks instability rather than resilience. Such instability drives up costs, increases exposure to external shocks, and ultimately weakens Europe's role as an industrial and economic powerhouse. Europe needs integrated planning that links production and networks, anticipates demand, and ensures that growth happens with foresight – not fragmentation.

> **"Europe should not shy away from long-term research in nuclear fusion – safer than fission and free of meltdown risk"**

Horizon Europe and the next budget

The next Multiannual Financial Framework shows that Europe intends to invest strategically. Programmes such as Horizon Europe and the Competitiveness Fund will support clean technologies and industrial renewal – but resources matter only if they reach the ground quickly and transparently.

In global competition, time is as decisive as funding. What counts are outcomes that strengthen competitiveness – from industrial innovation to the skills that turn ideas into results.

The Competitiveness Compass underlines this point: skills now stand beside investment and research as a pillar of Europe's strength. The European Parliament will ensure that funds are managed with transparency, oversight and clear strategic focus.

Skills: Europe's critical capacity

Technology alone will not determine success. We can design every artificial-intelligence system imaginable, yet they are of little value if we cannot use them with skill and purpose. We can install thousands of solar panels, yet they produce nothing if no one is trained to maintain them. Europe needs engineers and technicians – but also teachers and trainers who pass on expertise. Skills link research with reality.

The Draghi Report *inter alia* recommends closer ties between Erasmus+ and Europe's strategic priorities. Yet Erasmus+ remains far more than an instrument of competitiveness. It fosters cultural understanding, creativity and civic engagement – the very qualities that hold Europe together. Mobility and training, in all their forms, strengthen not only skills but a shared sense of belonging. A "Union of Skills" therefore means connecting universities, vocational schools and enterprises into a living network of knowledge and exchange.

Reskilling workers in changing industries is equally vital. Without new prospects, Europe risks losing both employment and trust. Skills are the social foundation of the Green Deal – they allow citizens to shape transformation rather than fear it.

In modern energy systems, this also means digital competence. Managing smart grids, protecting infrastructure and using data intelligently demands people who combine technical, green and digital expertise. Only then does innovation reach everyday life.

Energy Highways and market reform

Infrastructure decides whether innovation can deliver. Ursula von der Leyen's vision of "Energy Highways" captures this idea: grids that carry clean power across borders. Too often, bottlenecks in southern and eastern Europe still limit potential. The forthcoming Grids Package aims to close these gaps. By investing in interconnections, Europe can stabilise supply, balance prices and unlock renewable capacity.

> **"In some fields, Europe has built complex certification and reporting rules that slow down progress"**

The electricity-market reform of last year pursues the same aim: long-term contracts, protection from price volatility and a predictable framework for investors.

But stability cannot come from speed alone. Across Europe, photovoltaic and storage systems are expanding rapidly – a boom that now needs structure. Incentives for renewables must remain launchpads, not permanent subsidies. The transition must stay responsible, economically and environmentally.

Regulatory realism is essential. In some fields – hydrogen in particular – Europe has built a "regulatory Rolls-Royce": complex certification and reporting rules that slow down progress. Sometimes we must stop the clock, review the framework, and ask whether it still serves its purpose. Otherwise, we risk driving at full speed into a dead end.

For Europe's citizens, energy policy is felt in monthly bills; for businesses, in their ability to compete. Innovation and decarbonisation must therefore advance alongside economic stability.

Our political family has consistently stressed that Europe should avoid rules that add cost without tangible benefit. Reporting must be simplified, permitting accelerated and regulations streamlined to safeguard supply. Investment in interconnections lowers costs and strengthens resilience by allowing energy to circulate freely across borders. Above all, regulation should enable innovation rather than constrain it. Competitiveness depends on acting decisively – quickly, yet with judgment.

Europe in global competition

Europe cannot stand by while others set tomorrow's standards. Falling behind would mean losing industries and jobs. The answer is not a subsidy race but confidence in our own strengths: a vast market, strong research networks and a social model that keeps societies cohesive.

Future technologies will play a decisive role. Alongside hydrogen, offshore wind and energy storage, Europe should not shy away from long-term research in nuclear fusion – safer than fission and free of meltdown risk. Though not yet market-ready, fusion could become transformative if we invest now in science, infrastructure and people.

Strategic autonomy does not mean isolation. It means the capacity to innovate and produce essential technologies without fragile dependencies. It also requires reliable partnerships abroad. Europe's transition relies on cooperation for raw materials, green hydrogen and technology. Building such ties on fair and sustainable terms strengthens independence while anchoring us among trusted allies.

From policy to people

The energy transition succeeds only when it becomes tangible: in municipalities modernising utilities, in small firms investing in cleaner production, in universities training new experts, in workers learning fresh skills.

Institutions can set the framework, but progress happens locally – through collaboration between policymakers, industry and citizens. Transparency and fairness are not decorative values; they are prerequisites for success.

Europe stands at a decisive point. Energy policy is inseparable from research, innovation and competitiveness. The next EU budget offers a chance to invest in the technologies and skills that will define the decade ahead. Skills will determine whether citizens can seize these opportunities. Without trained people, even the best ideas remain idle. And without coherent planning and proportionate rules, determination alone will not suffice. Competitiveness will show whether Europe leads or follows.

The energy transition is not something that happens to us – it is something we choose to shape. With clarity, investment and a sense of responsibility, Europe can emerge stronger, more capable and ready for the future. ■

Advocacy

Digitising consumption data collection and using low-temperature systems can unlock decarbonisation potential

By Holger Hallmen, Dr. Arne Kähler, Joachim Klein, Sebastian Köster, Dr. Jochen Ohl, Andreas Pubanz, Kathrin Schleines, Linda Schmalz

In the current edition of the Techem Atlas we have analysed consumption and emission data for the year 2024 of around 100,000 apartment buildings with approximately 1.1 million apartments in Germany and additional 1.7 million apartments in selected European countries – making this analysis one of the most comprehensive of its kind. The Techem Atlas 2025 shows that the decarbonisation of Europe's multi-dwelling housing stock can be achieved by 2045 through targeted technical solutions. The in-house study provides reliable data on potential savings and illustrates that minimally invasive, low-investment approaches – especially submetering and related services – offer significant leverage.

Fossil fuels still play a significant role in most European countries

We found that final energy consumption for heating in multi-dwelling buildings in many European countries is surprisingly low. On average, these consumption figures fall into the energy efficiency classes C and D according to the German classification.

Fossil fuels such as heating oil and natural gas still play a significant role in most European countries. District heating is increasingly used but is still largely generated using fossil fuels.

The relatively low level of consumption is a good prerequisite for the desired transformation to low-temperature and low-emission or

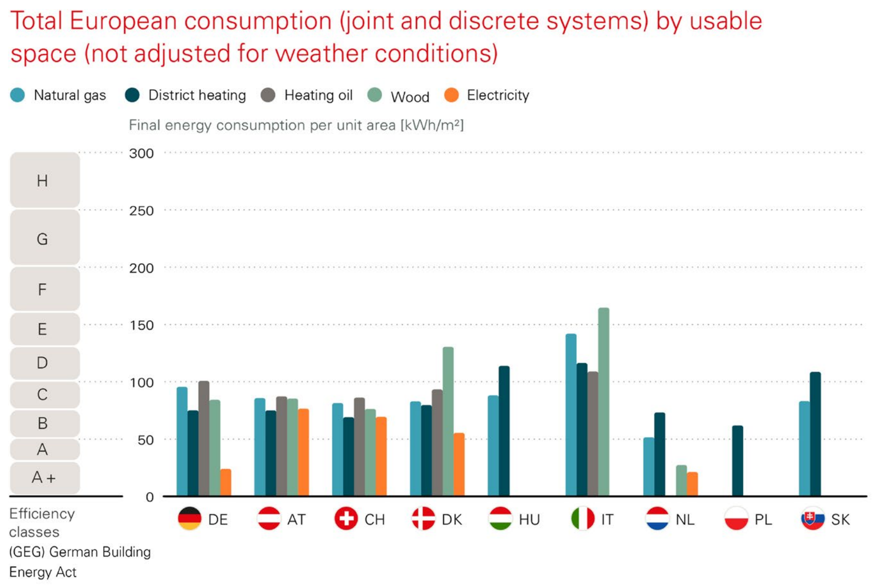


Figure 1: Total European consumption by usable space

emission-free energy sources such as green electricity and district heating from decarbonised heating networks. Low heat demands can be met with low system temperatures and enable high efficiency in heat generation via heat pumps and heating networks.

Consumption-based billing reduces CO_2e emissions by around seven million tonnes per year

Submetering is a reliable tool that provides tenants and landlords with detailed consumption information. Studies show an average 20% reduction in energy use if energy costs are billed annually based on consumption. Apartments in multi-family buildings in Germany without heating cost invoicing would emit around 2.1 tonnes of CO_2 equivalents annually. If heating costs are billed according to consumption, this reduces CO_2e emissions by around 0.43 tonnes per apartment per year. For Techem's national and international billing portfolio, this effect, in conjunction with the billing service based on the German Heating Costs Ordinance, results in an annual reduction in CO_2e emissions of around 7 million tonnes compared to a scenario without consumption-based billing.

More than 50% of the evaluated multi-dwelling housing stock can be decarbonised using low-emission, low-temperature systems

Based on the anonymised data we evaluated for our Atlas, we were able to show that the heating capacity reserves of the installed heating systems in many European multi-dwelling buildings are sufficient for the installation of heat pumps or for the operation of low-

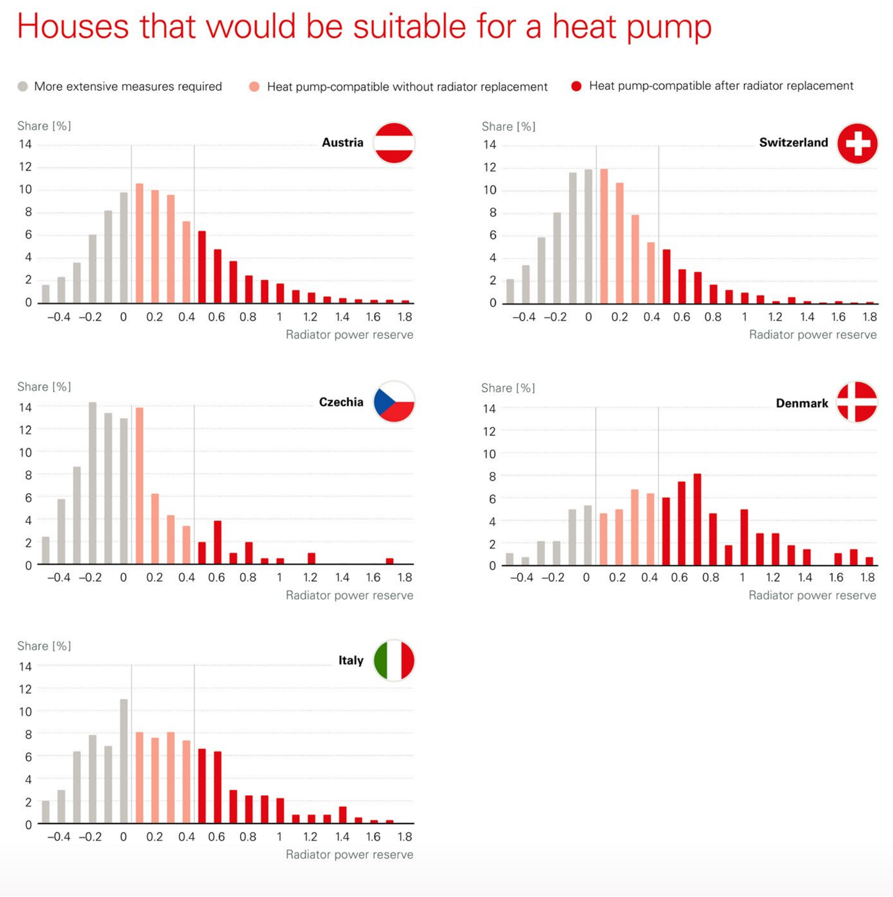


Figure 2: Houses that would be suitable for a heat pump

temperature district heating systems. Replacing radiators without additional insulation measures on the building envelope provides the necessary heating capacity reserves for low-temperature systems in typically more than 50% of buildings. This means that approximately 50% of the evaluated European multi-dwelling housing stock can already be decarbonised using low-emission, low-temperature systems.

Two levers for a successful heat transition: digitalisation and low-temperature systems

Decarbonisation will hardly succeed without digitalisation. Furthermore, according to the Directive (EU) 2023/1791 (Energy Efficiency Directive, EED), all installed metering devices must be remotely readable from 1 January 2027. Therefore, we also examined the digitalisation rate of consumption metering. The average digitalisation rate of 88.5 % achieved in 2024 shows that Europe has made significant progress in digitalising consumption metering. High availability of this data and its use for monitoring and control is crucial for the optimised operation of heat pumps and district heating networks. However, the average remote metering rate of 57 % indicates further potential that must be realised – ideally based on AMR (Automated Meter Reading) solutions rather than drive-by or walk-by technologies.

We recommend a two-step approach to ensure that decarbonisation is successful: firstly, low-investment measures such as monitoring and optimising operational management e.g. by using smart meters or the Techem Digital Heating Room. According to the study, this approach in 2024 saved 6.4 kilotonnes of CO_2 equivalents in Germany but also had a cost reduction effect of €3.2 million in 2024 only. Secondly, heating networks should be decarbonised, and a switch to heat pumps powered by emission-free electrical energy should be made. Since heat pumps have a high potential for energy loss, they should be continuously monitored and optimised in operation. The combination of monitoring, AI-supported control, and transparent consumption measurement is the key to greater efficiency and lower emissions – all with manageable investment requirements.

> **"Modern technologies, such as smart metering and the use of low-temperature heating systems, offer tremendous potential to accelerate decarbonisation."**

Cost-efficient technologies are a key factor in achieving decarbonisation

The findings of the Techem Atlas demonstrate that the heat transition in Europe's building stock is achievable and can be implemented with relatively low investment. Modern technologies, such as smart metering and the use of low-temperature heating systems, offer tremendous potential to accelerate decarbonisation. These solutions enable rapid scaling, are widely applicable, and lay the foundation for an emission-free heat supply. As such, they make a decisive contribution to achieving climate targets and transforming the European building sector.

Techem serves over 13 million households worldwide

Published annually, the Techem Atlas aims to increase transparency, track progress, and identify actionable steps for advancing the heat transition, based on 2024 data. Founded in 1952, Techem is a leading provider of smart, sustainable building services. Operating in 18 countries, 15 of which are in the EU, the company supports over 13 million households with around 68 million devices for measuring heat, water, cooling, and electricity – creating a digital infrastructure for efficient resource management and healthy living environments. ■

Ready for a deep dive? Read the full Techem Atlas 2025 here:

Institution insight

Solar flair

For decades, the JRC and ESTI have led the world in PV research and standard-setting. That knowledge now empowers European citizens in more ways than one.

By **Dr Christian Thiel**,
Head of the Energy Efficiency and Renewables Unit, Joint Research Centre of the European Commission

If you want to install photovoltaic modules on your roof, but don't know how much energy they may be able to produce in a year, how do you find out? You could use free online tools to do an estimate, or you could ask a local installer – who might use the same online tools that are available to you.

One of these tools, the Photovoltaic Geographic Information System PVGIS, developed and maintained by the European Commission's Joint Research Centre (JRC) is currently used by more than 15,000 visitors every day and processes nearly one billion data requests per year to perform such estimates. It is available in English, French, German, Italian, and Spanish. And in just a few steps – selecting your location, refining your settings if required, then clicking 'visualise results' – you can do your own PV energy estimates.

But let me take you on a little journey in time to reveal how we arrived at this tool, starting when the first commercial PV modules became available in the 1980s. Back then, PV technology was so new that there were no agreed measurement protocols or standards available for measuring the conversion efficiency and electrical power output of these devices. JRC scientists from the European Solar Test Installation (ESTI), a world-leading laboratory for the characterisation of PV devices, got to work and developed the first European standards both for the power measurement and the type approval of PV devices. This work laid the foundation for international standards that are still today instrumental in the success of PV as a global energy source.

"JRC scientists have analysed the photovoltaic rooftop potential of all 271 million buildings in the EU."

Yet, the power label of the PV module, which is part of the CE label on each PV module sold on the EU market, is not the same as the expected energy that the module could generate on your rooftop. The reason is that the power rating is determined under laboratory test conditions with an irradiance of a standard light spectrum and 1000W per m2 and a temperature of 25°C. The light spectrum and irradiance mimic direct sunlight that arrives on the earth's surface under clear sky conditions around midday. Of course, you will only occasionally find these conditions on your rooftop throughout an entire year, and as a prosumer you are more interested in how much energy you will generate. Hence, you need to understand the expected energy output of a PV device under all the conditions that you will experience during a given year and location.

That is why JRC scientists of the ESTI laboratory led international efforts to develop an energy rating standard that establishes a measurement protocol for PV modules under various light and temperature conditions. This is then used as a basis to match the measured values with different climatic zones. It is also the basis for a new label that the European Union is currently exploring for PV modules. The new label would provide information on the expected energy output of a given PV module for different climatic zones in Europe. As such it would enable prospective buyers of PV modules to compare different PV modules with each other so that they can make a well-informed choice.

A solar simulator provides a close spectral match to real sunlight

The JRC scientists have then decided to combine their detailed laboratory data with climate data in the popular PVGIS tool, and make this available as a free online version for everyone. The tool basically applies the principles of the energy rating standard with a higher granularity as specific local conditions are considered, thanks to the use of high-resolution satellite and re-analysis datasets that provide European and worldwide coverage.

The main users of PVGIS are citizens, installers, project developers, researchers, professors and students. The tool is very flexible and supports, besides individual simulations, also bulk requests. This function enables larger feasibility studies, for example the potential of PV deployment on buildings or along highways and rail tracks, on water reservoirs, potential impacts of high PV shares on energy markets. They also allow the seamless integration of PVGIS into other tools.

In a recent study, JRC scientists have analysed the photovoltaic rooftop potential of all 271 million buildings in the EU. Here they made use of the PVGIS tool together with another exciting database that JRC scientists have developed and published free for everyone to use, the European Digital Building Stock Model. In a massive number-crunching exercise, they have combined these two to establish a first-of-a-kind solar rooftop cadastre for the entire EU. It turns out that there is vast potential in the EU for rooftop PV.

Of course, this is just the technical potential and many other factors need to be addressed before this potential can be fully leveraged, notably flexibility measures, grids, and energy storage, just to name a few.

The development and deployment of photovoltaics is a European success story. The laboratory and desktop research work of EU scientists helped establish the standards that are an important basis for the success of renewables and enabled the development of related digital tools which empower citizens, energy communities and businesses to actively shape the energy transition based on their own well-informed decisions and also support scenario work for further renewables deployment.

Currently, JRC scientists are working on a complete modernisation of PVGIS that in the future will enable start-ups and scale-ups to develop their own tailor-made solutions, and allow other scientists to benefit from the know-how of the JRC scientists and ESTI laboratory. One thing is clear – there is still a lot of upside potential for renewables in Europe, and better access to data and tools can play a crucial role in turning this into a sustained success story for the EU.

This is just one example of how JRC scientists provide independent, evidence-based knowledge and science, supporting EU policies to positively impact society. Many other examples could be given, be it in the domains of energy, mobility, and climate, or practically all other policy files of the EU. ■

"There is still a lot of upside potential for renewables in Europe, and better access to data and tools can play a crucial role in turning this into a sustained success story"

About the author

Dr Christian Thiel is Head of the Energy Efficiency and Renewables Unit at the JRC. He supervises science for policy work for European energy efficiency and renewables policies as well as city climate action. He joined the European Commission in 2009, having worked in the automotive industry before. Christian holds a Doctoral degree (Dr.nat.techn.) from the University of Natural Resources and Life Sciences Vienna, a Master's degree in Environmental Science (Geooekologie) from the Technical University Braunschweig, and a bachelor's degree in Biology from Université Paris VI.

Special feature

Celebrating 15 years in print

European Energy Innovation was founded in November 2010. To mark its birthday, we asked our friends to share their reflections on the past 15 years – the highs, the lows, the milestones reached and the obstacles overcome.

Ed Wiseman,
Editor, *European Energy Innovation*

Fifteen years ago, long before I joined *EEI*, I was working as an automotive journalist for a small British newspaper. My job was to review every new car before it went on sale, and explain to my readers why it was different from any other A- or B-segment hatchback they may have been considering.

Because 2010 was a different time. The Ford Focus, Ford Fiesta and Vauxhall Astra were the three most popular models in the UK, just as they had been ten years earlier. The rest of the sales chart was led by European brands, and powertrains were split almost 50:50 between gruff 2.0-litre diesel engines and small-displacement turbocharged petrols. In 2009, just 55 electric cars were sold in the UK, over the whole 12-month period.

A few months later, Nissan introduced the Leaf, changing everything. This slow, goofy hatchback, with its low range and high price, was the first mainstream EV and probably the single most influential car I have roadtested from a wide field of candidates. The Leaf, now in its third generation, is joined on UK forecourts by over 100 other electric models; in contrast with 2009, UK EV sales in September 2025 alone stood at 72,779.

It's difficult to reflect on this time frame without mentioning China's rise to prominence, which has also taken place almost entirely within the span of my not-particularly-long career so far. From the mediocre MG6 saloon to the memorably bad Great Wall Steed pickup truck, Chinese cars in the early 2010s didn't threaten European manufacturers' longstanding prowess; in the EV era, China has a firm grip on drivetrain supply chains and its own car brands are gaining popularity with British buyers with attractive prices and improving quality. This all happened in a couple of four-year model cycles. Even London's iconic black cab is now built by a Geely subsidiary.

I could talk at length about how cars have grown in size (by about 5mm per year, on average, since *EEI* was founded in 2010) or about the oft-overlooked advances in e-bike technology or commercial vehicle electrification. I could mention the changing language we use to describe transport; at the start of my career, my patch at any given newspaper was called "motoring", whereas today I come under "mobility". But by far the biggest shift I have experienced – bigger than the switch to EVs – has been in journalism, digital publishing, and the media as a whole.

Instagram and *EEI* are around the same age. Twitter and YouTube are a bit older, Snapchat younger. Google+ came and went between issues three and 34. Social media is ubiquitous, and has given everybody in Europe not just the ability to share content with the world, but to see how much the world likes it.

> **"In 2009, just 55 electric cars had been sold in the United Kingdom"**

That's as true of a teenager counting the 'likes' on her TikTok as it is of an editor at the *New York Times* reviewing the traffic data and dwell time on a long-form investigative feature. The attention economy demands that we all monitor and respond to such data, though it's the press, which relies on traffic to generate advertising revenue, that web analytics has in a stranglehold. Now that editors can know, in real time, precisely what stories are popular and therefore profitable, why wouldn't they focus their editorial efforts on those subjects? And why, knowing that other subjects are less lucrative, would they bother investing in them at all?

As a journalist, I am often asked by mainstream publications to write an article based on what the "audience development" team identifies as a popular topic; more insidiously, we are frequently instructed to abandon particular issues if insufficient reader demand is detected by the algorithms. Editors have long been incentivised to prioritise stories that sell newspapers, but never has the tail wagged the journalistic dog as much as it does today.

Guilherme Cardoso,
Nuclear Technology Advisor,
Nuclear Europe

In 2010, when talk of a "nuclear renaissance" was everywhere, confidence in the nuclear sector was high. Projects were being planned across Europe, climate policy and energy security pointed in the same direction, and there was a genuine sense of momentum.

Fukushima in 2011 abruptly changed that trajectory, and the arrival of cheap natural gas further dampened new-build ambitions.

Now, in 2025, the drivers are familiar, although with different relative importance. Climate change is still a central concern, but the new nuclear momentum is now primarily about energy security and sovereignty. European countries want to wean themselves off imported fossil fuels, particularly from unreliable suppliers such as Russia, and nuclear is back on the table as a strategic asset.

Technically, we have not stood still. Lifetime extensions are now largely recognised as the cheapest way to produce electricity, and the life of the vast majority of European reactors is expected to be extended.

Digitalisation is transforming design, construction and maintenance. At the same time, Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs) promise more flexible deployment, innovative fuel uses and designs optimised for co-generation of electricity, heat and hydrogen. On the policy side, the inclusion of nuclear in the EU Sustainable Finance Taxonomy was a major milestone, helping to normalise a debate that was taboo for years. Its recognition in the Net Zero Industry Act and low-carbon hydrogen legislation further reinforces that shift.

Looking ahead to 2040, the rapid rise of energy-hungry data centres, industrial decarbonisation and electrification add further reasons to be ambitious. If Europe wants resilient, low-carbon infrastructure, nuclear will have to shoulder a significant share of those 24/7 energy needs.

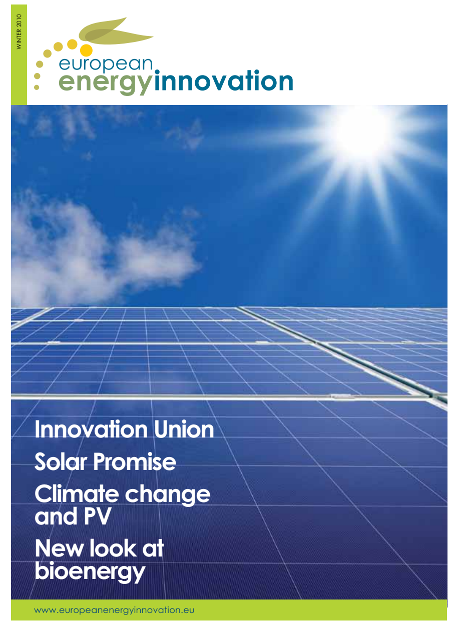
Tudor Constantinescu,
Principal Advisor to the Director General for Energy, DG ENER

Looking back on the 15 years since the first issue of *EEI* was published, energy has become an ever more central policy area. The main political driver was the commitment to addressing climate change, crowned by the commitment to climate neutrality by 2050 made under the first Von der Leyen Commission. More recently, energy security and energy affordability have grown in importance.

During the same period, pushed by the political direction, investments in R&I and deployment of renewables, storage and energy efficiency solutions started to pay off and to bring down the cost of clean energy, by over 80% for PV, about 70% for wind, and almost 90% for batteries and electrolysers for hydrogen production.

The share of clean power generation in the EU is more than double compared to fossil fuels. And improvements in energy efficiency over the period were also significant, although more potential remains to be tapped. Developing markets and regulatory frameworks adapted to the new technological developments and enabling the faster deployment of renewables and energy efficiency became increasingly a necessity.

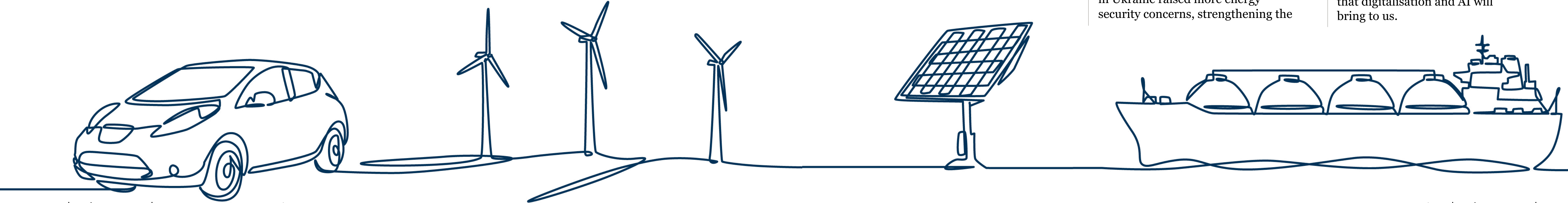
A major push was given to the energy transition with the Fit for 55 package. Accelerating the energy transition, making more investments and increasing the CAPEX in the short term would reduce the operational costs in the longer term, and accelerate modernisation of the energy infrastructure, of the industry and of the building stock. This modernisation and investments required build into the Clean Industrial Deal pillars, driving the competitiveness of the European economy. At the same time, the Russian invasion and war in Ukraine raised more energy security concerns, strengthening the case for an accelerated energy transition.



The first edition of EEI

Looking into the future of the energy system several challenges remain: geopolitical, crisis prevention and response, affordability, the gradual shift away from fossil fuels, the dependence on critical raw materials, the coexistence of distributed and centralised power generation, the need for strengthened infrastructure at both transmission and distribution level, the decarbonisation of the parts of the economy that cannot be easily electrified.

A more integrated energy system, the building up of value chains, the diversification of imports, the implementation of policies in partnership with industry and stakeholders should pave the way for the transformation of the energy system. In this transformation, perseverance on climate objectives on one hand, and technologies and solutions supporting flexibility and adaptability on another hand will have to coexist as main principles, and make the most effective and responsible use of the progress that digitalisation and AI will bring to us.



Europe's Rail Joint Undertaking,
Ed Wiseman,
Editor, *European Energy Innovation*

EU-Rail and before it the Shift2Rail Joint Undertaking (S2R) have reshaped the landscape of rail research and innovation in Europe. These initiatives have enabled the development of key technologies and contributed to the harmonisation of the European rail system.

Within S2R, 695 prototype testing activities were carried out up to 2023 with technology validated or demonstrated in relevant environments.

This development progression continues in EU-Rail with many technologies reaching higher TRLs (7 and 8). As an example of Europe's Rail work, the European DAC (Digital Automatic Coupler for European rail freight) Delivery Programme aims to boost capacity, productivity, and quality, creating a more efficient and modern European rail freight system.

Furthermore, the first autonomous passenger train in Europe, EDITA, was demonstrated in the Czech Republic, validating GoA4 (grade of automation) functionality and proving interoperability of components from multiple suppliers.

In the Netherlands, Remote and Autonomous Shunting & Stabling was demonstrated, with trains operated 120km away and fully autonomous functions including cab selection, mission execution, obstacle detection, and automatic driving.

The technological breakthroughs developed in EU-Rail significantly enhance safety, operational efficiency and reliability of the rail system, while contributing also to cost reduction and to European sustainable and green mobility as a whole.

A new Joint Undertaking, building on S2R and EU-Rail, will make rail a more attractive transport option for both passengers and freight operators, supporting the EU's climate and mobility objectives and long-term sector competitiveness.

Jorgo Chatzimarkakis,
CEO, Hydrogen Europe

Over the past 15 years, the European Union has built one of the most remarkable innovation instruments in the clean-tech landscape: the Clean Hydrogen Partnership.

I had the privilege, as a Member of the European Parliament at the time, to help shape what was then called the Fuel Cell and Hydrogen Joint Undertaking. It became a cornerstone for Europe's innovation policy, enabling real progress in electrolysis, fuel-cell mobility, and the first large-scale demonstrations of a hydrogen economy.

The next fifteen years will be decisive. The challenge is no longer to prove that hydrogen works – it does – but to industrialise and scale what Europe has already invented before our international competitors dominate the market.

While Europe has been refining its regulatory framework, China has moved ahead with a bold integration of hydrogen electrolysis and fuel-cell technologies into its Five-Year Plan, turning innovation into market dominance. If Europe does not accelerate, it risks repeating the pattern of solar panels and batteries – brilliant R&D, followed by an exodus of manufacturing capacity to other parts of the world.

The opportunity, however, remains open. Hydrogen can still become Europe's strategic asset, not only for climate neutrality, but for resilience, energy security, and a circular industrial economy.

Linking hydrogen to dual-use technologies and domestic energy autonomy will be key. The next chapter of Europe's hydrogen journey must transform innovation excellence into resilient self-sufficiency – and that requires speed, pragmatism, and political will.

"If Europe does not accelerate, it risks repeating the pattern of solar panels and batteries – brilliant R&D, followed by an exodus of manufacturing capacity to other parts of the world"

Europe's priorities have shifted since 2010

Prof. Åse Gornitzka
President, European Cooperation in Science and Technology (COST)

COST is an EU-funded programme that enables researchers and innovators to set up interdisciplinary research networks in Europe and beyond. COST does not fund research itself but provides support for networking activities on a wide range of scientific and technological fields.

Over the past 15 years, COST has pursued its mission by fostering bottom-up, excellence-driven, open, and inclusive networks. These networks have made significant contributions, including areas such as climate-neutral and smart cities, sustainable energy solutions and the assessment of climate change impact. And these networks have proven to be vital platforms for interdisciplinary collaboration, connecting experts from diverse disciplines, institutions, and countries.

Today, COST continues to strengthen Europe's capacity to address scientific, technological and societal challenges by providing networking opportunities for researchers and innovators.

This inclusive approach ensures that scientific excellence extends beyond regions or institutions, fostering collaboration across the entire continent and strengthening the EU's collective ability to respond to its most pressing societal challenges.

In the long term, by empowering researchers, fostering collaborations, engaging diverse research communities, and aligning with broader European and global priorities, COST networks are positioned to extend their influence well beyond the end of their formal funding period.

The results of the collaboration established during their implementation provide a strong foundation for continued research excellence and meaningful, lasting impact across the European Research Area and the wider global research landscape.

Jens Holm,
Policy Director, European Solar Manufacturing Council

Fifteen years ago I was a new member of the Swedish Parliament, responsible for climate policy. I remember how we viewed the European solar manufacturing industry, with pioneering companies such as SolarWorld, Q-Cells, Photowatt and Isofotón. Thanks to Germany's Energiewende and ambitious feed-in tariffs, Europe supplied a large share of the world's solar modules. It was a moment of optimism and innovation.

The rollout continued, with record installations every year, and PV moved from a niche technology to a mainstream energy source. But at the same time, China chose to build its own solar industry – protected by subsidies and unfair conditions, from repression against workers, dumped wages, to weak environmental rules. Today we are reaping the consequences of Europe's lack of an industrial strategy. More than 90 percent of global solar components now come from China. I struggle to think of any other industrial sector that has been lost so quickly – and with so little political response.

But I haven't lost faith. The same continent that once led the world in solar can do so again. At the European Solar Manufacturing Council (ESMC), we work every day to rebuild that capacity – to make solar clean, fair and resilient. That means cutting all links to forced labour, rewarding those who manufacture sustainably in Europe, and matching our competitors' industrial ambition.

Solar is now the cheapest and fastest-growing energy source. With it, we can finally and decisively phase out deadly fossil fuels and truly transform our world into a just and sustainable society. But we cannot do that while being so dependent on one single supplier – let alone a dictatorship where oppression and forced labour are systemic. It's time for Europe to shine again.

Lothar Schupet,
CEO, Zeekr

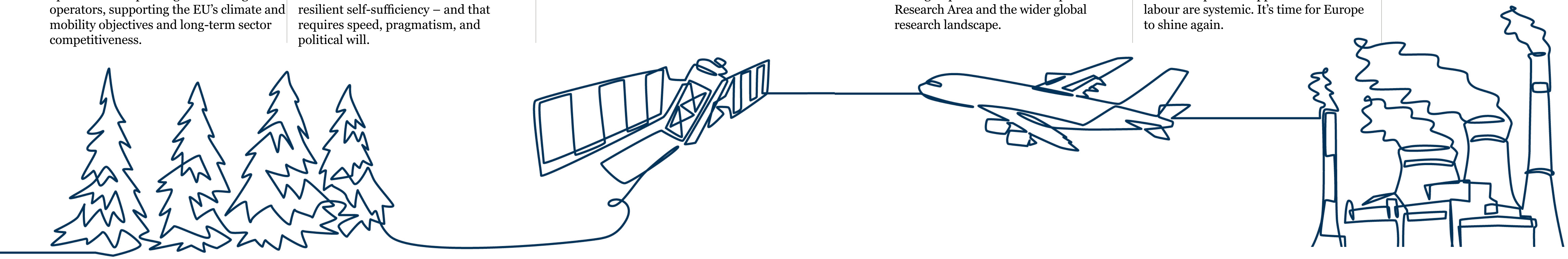
Remember fifteen years ago, when the industry committed to all these efficiency measures like downsizing petrol engines and adding turbochargers to make them more fuel-efficient? And then the first EVs came along and we realised we could do all that without any consumption at all. This era moved fast – renewable energy is making mobility sustainable and clean – and the race is now about range, charging speed, and removing all the anxieties.

Look at what we've just announced – a car with a 1,000km range and a charging speed of seven minutes from 10-80%. Were already in the era of an EV with no disadvantages, provided the infrastructure is there.

There are developments in e-fuels but these don't seem promising. I believe in the next five to ten years, there will be a big acceleration [in EV tech] and in L4 and "robotaxi" technology. In the next 15 years, Europe will get the same autonomous charging solutions and other technologies that are becoming available in China.

Like every technology jump, smaller regulators – cities, communities, smaller entities – will want to prove themselves and will drive change. I wanted to initiate robotaxis more in Europe, but it's not easy at the moment to move forward. I think this will be simplified.

To read more from Lothar Schupet about electric vehicles, charging infrastructure and the inevitable rise of Chinese car brands in the EU, pick up the Spring edition of *EEI*, which will include a special transport and mobility section.



Patrick Clerens
Secretary General, Energy Storage Europe Association (EASE)

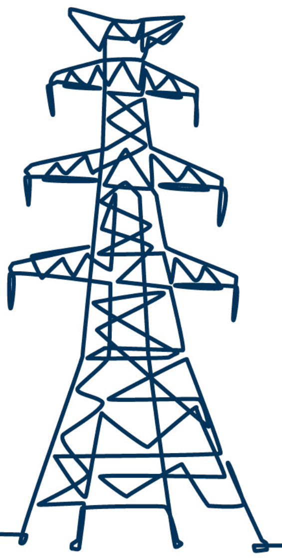
While in 2010 energy storage was seen as a niche, and new in the energy sector, today it is a cornerstone in providing flexibility to the system, integrating weather-dependent renewables and lowering energy prices. Europe's total storage fleet has grown to almost 100GW across technologies, with batteries expanding rapidly alongside long-standing pumped hydro.

In November 2025, a 1GW battery energy storage system was announced in Germany. This is comparable to a single nuclear unit. The scale of new projects shows how quickly storage is maturing.

Energy storage incorporates different technologies that will help Europe decarbonise and keep electricity reliable every hour of the year. Looking ahead, EASE estimates the EU needs ~200GW of storage by 2030 and ~600GW by 2050 to meet its climate and security goals.

In order to continue on this path, the regulation also has to keep up. Energy storage can play a key role in alleviating issues in grid connections, reducing congestion along with network tariffs. Ending double charging, introducing time-of-use and locational signals, and making grid connections smarter and more transparent are immediate priorities that unlock investment and lower bills. EASE is working on these issues and has seen positive developments at EU and national level.

Reaching our climate targets and net-zero necessitates fit-for-purpose legislative developments as well—and that's key for our energy security. Because we need to produce and store energy in Europe, rather than importing it from abroad.



Greg Arrowsmith
Secretary General, EUREC

Remember Jean-Claude Juncker, who declared in 2014 that Europe should be "the world number one in renewable energies"? We never did hear him unpack that, but assumed he aspired to world leadership in research, development and demonstration of renewable technologies.

A leap forward did come. 2017 was the year when the cost of offshore wind, as suggested in the bids being made by developers for concessions, plunged and the sector took off. That changed the game and made higher targets for the deployment of renewables than the proposed 27%-by-2030 realistic.

But "world leadership" in the all-important technology of photovoltaics remains a long way off. Even a place on the podium would be an improvement, and we won't get there unless we have a multi-GW revival in PV manufacturing.

How to manifest those elusive fabs? With grants and financing, yes, but also protectionism. Remember when DG GROW's defence of industry policy consisted of releasing a new industrial strategy communication every two years? Those mice ultimately brought forth a mountain: the Net Zero Industry Act, in 2024. Its push for the use of non-price criteria in auctions for public RES support is a revolution, but it still falls short: legislation that mandates products 'made-in-Europe' is the next step.

In the medium term, the use of 'made-in-Europe' must give way to the use of 'innovation' criteria, i.e. privileges in access to public funding should be directed at high-performance products. Relieved from external pressure to deliver technological progress through exposure to competition, shielded European companies must instead feel an internal pressure. If their products fall behind those available outside, they will face a brutal reckoning. I don't hear this concern expressed enough.

The EU's competitiveness lodestar should be 'embrace electrification in all its forms': follow China down that path and leave the US, under its current administration, to shoot itself in the foot.

Dušan Jakovljević,
EEIP

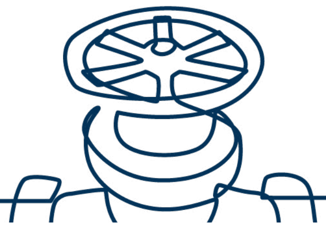
After two decades of working in the communication of energy transition policy, I have watched many promising energy-efficiency innovations rise, and quietly fade. Technologies work, pilots impress, reports celebrate success. Yet replication often fails to get started as the conversation gets lost in translation.

Energy efficiency is less a physical problem than a linguistic one. Engineers, financiers, policymakers, and citizens speak different dialects of the same ambition. The engineer calculates kilowatt-hours saved; the financier weighs payback time; the policymaker measures compliance; the citizen feels comfort and cost. All are correct and all misunderstand each other. What should be a shared project becomes a set of disconnected conversations.

While working on EU policy in the UK years ago, I was intrigued by Prof. Richard Freeman's paradox that "policy is the output of a series of communications, not its input". Innovation, in other words, doesn't exist in finished form waiting to be copied; it is created in the very act of being shared. When we try to "transfer" a project from one place to another, we're not moving an object, we're rewriting a story.

Over the years, I've learned that true diffusion depends on 'translators', the intermediaries and enablers who make meaning convey. Development banks, energy agencies, accelerators, ESCOs, and networks have a role to serve as what Freeman called boundary objects: they create shared frameworks, standards, and narratives that allow engineers, investors, and citizens to finally talk about the same thing. Their real power lies not in money or mandates, but in their ability to align language, values, and incentives.

To conclude, I've come to see communication itself as the missing infrastructure of the energy transition. We don't need to speak one language, but we do need to listen across them. Because in the end, innovation doesn't spread by being copied. It spreads by being understood.



The *European Energy Innovation* team would like to thank the hundreds of writers, researchers, policymakers and innovators who have contributed to our magazine since it was founded in 2010.

We would also like to thank our readers, from the energy professionals who have been subscribers from the very start, to the early-career researchers who are picking up a copy for the first time.

EEI is proud to work with and alongside some of the green transition's biggest names, and many more of its unsung heroes. We look forward to connecting the European energy community in 2026 and beyond.

Thank you.

On the radar

In this mini-dossier on sustainable flying, *EEI* turns to three of Europe's foremost aviation innovators for a quick report from the field

LUFTHANSA GROUP ONERA CLEAN AVIATION

Photo: Falaq Lazuardi

Aviation and innovation

Frustrations aside, Europe is slowly approaching a golden age of green aviation

By **Lizzie Meager**

Europe's ambitions for clean air travel is no longer a distant aspiration. Instead, the measurable and increasingly tangible results of a sector in transition are beginning to appear – alongside signs of how steep the climb ahead will be.

Under the ReFuelEU Aviation framework, which is part of the broader Fit for 55 package, 2025 marks the first year when fuel suppliers at EU airports must supply at least 2 percent sustainable aviation fuel (SAF).

The 2024 data are now in. According to October's annual technical report from the EU's Aviation Safety Agency (EASA), SAF accounted for 0.6 percent of all aviation fuel supplied at airports across the bloc in 2024. That's around 193 kilotonnes of SAF, equating to roughly 714 kilotonnes of avoided CO2 emissions. That may sound modest to the casual passenger, but it's roughly equivalent to 10,000 flights between Madrid and Paris.

Importantly, nearly all of 2024's SAF came from bio-based sources, mainly used cooking oil (approximately 81 percent) and waste animal fats (approximately 17 percent).

This underscores two truths. The first is that SAF is real and being used today, and second is that the shift from first-generation biofuels to next-generation synthetic e-fuels (e-SAF) is still nascent. The EU's targets for e-fuel content – starting with 1.2 percent of total aviation fuel by 2030, rising to 35 percent by 2050 – remain a long way off.

Engineering momentum builds

At the same time, 2025 has seen serious progress on the propulsion-system front. At an Airbus summit in March, the company reaffirmed its commitment to hydrogen-powered flight under its ZEROe project, unveiling a concept aircraft powered by four 2MW electric engines driven by hydrogen-fuel cells.

Airbus has said that integrated testing of fuel-cell stacks, electric motors, inverters and heat-exchange systems progressed in 2024, and development of a test platform for safely storing and pumping liquid hydrogen on the ground – essentially a full-scale mock-up of the infrastructure an airport would need – has advanced in Grenoble, with full ground-testing planned for 2027.

On the operational side, momentum is building beyond fuel and propulsion. This year, EUROCONTROL updated its FlyingGreen platform, enhancing emissions-forecasting, fuel-burn modelling and "what-if" tools. This will help airports, airlines and air-traffic regulators explore investment decisions tied to SAF, hydrogen, or electric aviation.

In Spain, air-navigation operator ENAIRE reported that, against a backdrop of rising traffic, its improved airspace and flight-management efficiency cut some 3.6 million flight-kilometres in 2024, avoiding around 68,000 tonnes of CO2.

Windowless cabin concepts are being explored, using internal displays to cut weight, improve aerodynamic efficiency and, presumably, display adverts.

Europe's sustainable aviation transformation is no longer just a planning exercise. Tangible innovations are beginning to take flight, physically as well as metaphorically. But the ascent from laboratory to fully decarbonised, economically viable commercial flying remains as steep as expected in a notoriously hard-to-abate sector.

Next up for European innovation

For 2026, the industry is likely to see a tug of war between the urgency to scale SAF and eventually e-SAF, the technical complexity and cost of hydrogen or hybrid aircraft, and the practical realities of air-traffic growth, infrastructure build-out, and regulatory harmonisation.

Regional hybrid aircraft might see their first real demonstration, while airports are likely to accelerate retrofitting heating, logistics and fuel infrastructure to save emissions on the ground.

We are finally seeing SAF in the tanks, early hydrogen propulsion systems in the lab, and real-world infrastructure upgrades. Whether that becomes a full-blown zero-emissions aviation industry – or rather, when – will depend on whether policy momentum, industrial investment and engineering breakthroughs all align in the years head. ■

AeroSHARK in use on three continents

LUFTHANSA GROUP

The Lufthansa Group is the first airline group in the world to equip its aircraft with the innovative "shark skin". Several airlines have since adopted Lufthansa Technik's AeroSHARK drag-reduction technology across an increasing number of aircraft. Today, 30 aircraft worldwide operate with the AeroSHARK modification, each delivering fuel savings and lower CO_2 emissions.

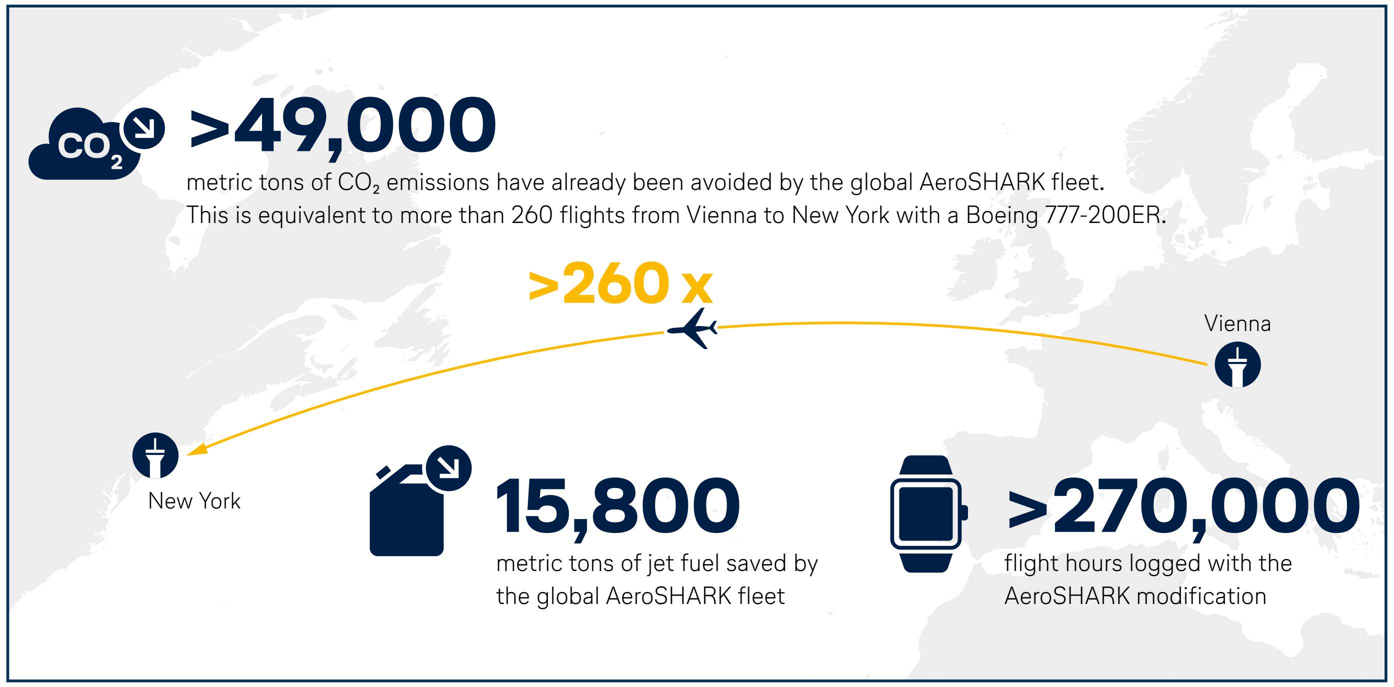
The functional service film developed by Lufthansa Technik and BASF is modelled on the skin of a shark and is applied to the aircraft's fuselage and engine nacelles. It reduces frictional resistance during flight and thus lowers fuel consumption by up to one percent. The Lufthansa Group has now equipped 22 of its aircraft with this innovative technology. The group's entire AeroSHARK fleet thus saves more than 20 metric tons of kerosene and more than 60 metric tons of CO2 every day.

The success story of the "shark skin" continues. Lufthansa Technik has begun certifying AeroSHARK for the Airbus A330ceo, which will significantly expand the technology's reach across long-haul fleets. In addition, airlines outside the Lufthansa Group are now also applying the surface technology. Currently, three carriers from Asia and South America are using AeroSHARK on their passenger and cargo aircraft. Lufthansa Technik is training their maintenance staff on site and is supporting the airlines during the initial installation. With the current global fleet of 30 aircraft equipped with AeroSHARK, more than 49,000 tons of CO2 emissions have already been avoided. This is equivalent to more than 260 flights from Vienna to New York with a Boeing 777-200ER.

Nature as a Blueprint

With a microscopic structure, the 50-micrometer-thin film imitates the unique properties of shark skin. Countless tiny riblets reduce air resistance and thereby lower fuel consumption. In the current development stage, CO2 emissions can be reduced by up to one percent. This makes AeroSHARK a prime example of bionics technology inspired by nature. ■

Scan to find out more about AeroSHARK



Advocacy

How ONERA pioneers the decarbonisation of future aviation

French aerospace laboratory ONERA is at the forefront of aircraft design and its innovations contribute significantly to the future of clean air travel

ONERA
THE FRENCH AEROSPACE LAB

“Ensuring a future of sustainable aviation does not come down to limiting CO_2 emissions.”

As France’s premier aerospace research establishment under the tutelage of the French Ministry of the Armed Forces, ONERA also performs scientific research in the field of civil aeronautics. Our work is now instrumental in decarbonizing future aviation in order to reach the ambitious Long Term Aspirational Goal in 2050: a climate neutral aviation. Serving as a trusted state expert for numerous subjects for authorities like the DGAC (Direction Générale de l’Aviation Civile), we collaborate closely with European and French industries, and are participating in various EU projects (including in Clean Aviation partnership).

Breaking technological barriers for reduced climate impact

Decreasing the carbon footprint of aviation necessitates introducing game-changing technologies that surpass those of current aircraft configurations, already highly optimized. Our objective is to achieve maximum energy efficiency, which requires advanced optimization and high-accuracy design tools. We are currently working to mature two pivotal innovations for the next generation of commercial aircraft.

Open-fan engine: A turbofan engine with an unshrouded fan that allows dramatically increasing the by-pass ratio and thus the propulsive efficiency. ONERA actively collaborates with Safran on the development of the Open-Fan engine. Extensive testing campaigns have taken place in our Modane wind tunnels as part of our partnership with Safran, complementing numerical simulations and noise reduction research. Additionally, ONERA works with Airbus to optimize the integration of the engine into the aircraft and explores novel aircraft configurations to enhance the environmental performance of commercial aviation.

High-aspect-ratio wing: Characterized by an exceptionally long wingspan with a comparable wing area, high-aspect-ratio wing is a solution to reduce the induced drag of the aircraft. It poses flexibility and aerodynamic load recovery issues while maintaining a slender aerodynamic profile. ONERA’s exploration of the braced wing concept offers a viable solution to reconcile these constraints. Once again, our aerodynamic simulation tools have improved design efficiency.

Globally speaking, the aim is to reach 30% fuel burn reduction in 2035, combining Open-Fan engines and High-Aspect-Ratio Wings, together with the use of always more efficient materials. In this field, ONERA research teams are very active too, keeping in mind the specifics of materials in Aeronautics: they have to be light (thus, use of composite instead of metallic materials is very attractive) and simultaneously operate in very severe environments (mechanical loading, temperature, atmospheric environment, humidity). One of the challenges in the coming years will be to develop these materials, thanks to a very fine modeling and understanding of the many different scales in aeronautics (from atomic scale to the scale of the structures), making extensive use of Artificial Intelligence techniques (deep learning).

Beyond aircraft efficiency, decarbonizing the energy used by the aircraft is key for tending towards the zero emission target required for a climate neutral aviation. ONERA has been a pioneering actor in France and Europe for the study of the use of sustainable aviation fuels (SAF). Today, we are still performing research on the acceptability by aircraft fleets of pure synthetic fuels with a view to European targets in terms of SAF incorporation.

New aircraft configurations

A typical example is the BWB (Blended Wing Body) which, as an alternate to conventional tube and wing configurations, is attractive to integrate breakthrough technologies in a longer term, such as H2-burn combustors, distributed propulsion, and buried engines, among other concepts.

However, ensuring a future of sustainable aviation does not come down to limiting CO_2 emissions. Other emissions of aviation such as NOx or particles emissions are involved in aviation climate impact through complex chemical and physical mechanisms, one of the most important one being the formation of contrails that can evolve in cirrus clouds.

Nonetheless, the uncertainty of their actual effect is today still high and ONERA carries out research on the physical mechanisms in play in their formation and on the modelling of their properties. ONERA cooperates with the French climatology institute Institut Pierre Simon Laplace (IPSL) in the CLIMAVIATION national initiative supported by DGAC to integrate its results in a climate assessment of contrail effect. ONERA is also active in research for mitigating contrail effects through aircraft route optimization under climatic constraints.

No compromise on safety

Aviation has been successful for decades because it has demonstrated unrivaled levels of safety. Breakthrough technologies inherently come with new risks that require a deep understanding of the physics. ONERA is mandated by DGAC to work on certifiability of new technologies in order to understand and lower these risks, following a rigorous scientific approach (lightning, icing, fire, crash…). Here again, the combination of digital and experimental approaches is key to progress in this field (for example, the PyCoFiRe new test rig to study fire risks in engine compartments at Le Fauga ONERA center).

A research with high impact

Investing in upstream research is essential to develop differentiating technologies that will safeguard European competitiveness and serve European citizens through improved services. As an example, ONERA recently developed through the Sesar EU partnership a tool called SINAPS that helps organizing the air traffic control rooms. Based on Artificial Intelligence algorithms, this tool is now operational in the all-national en-route centres, contributing to seamless air traffic control.

“All the major civil and military aerospace programs in France and Europe carry a part of ONERA’s DNA: Ariane, Airbus, Falcon, Rafale, missiles, helicopters, engines, radars…”, as ONERA CEO Bruno Sainjon says. Undoubtedly, ONERA remains at the centre of the European aviation research and all our researchers are strongly committed to making the European sky of tomorrow ever cleaner and safer. ■

“ONERA is also active in research for mitigating contrail effects through aircraft route optimization under climatic constraints”

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Advocacy

"Let's not focus on just one technology"

AVIATION RESEARCH & INNOVATION STRATEGY

A focus on multiple technologies is essential, explains Clean Aviation executive director Axel Krein in this interview about the Aviation Research and Innovation Strategy (ARIS)

Interview with **Axel Krein,** Executive Director, Clean Aviation

What are the fundamental challenges facing the European Aviation Industry in the years to come regarding competitiveness and sustainability? What measures are needed and what should be the EU's role? ARIS, the Aviation Research and Innovation Strategy, aims to answer these pressing questions against the backdrop of current discussions on the EU's next long-term budget. We caught up with Axel Krein, Executive Director of Clean Aviation, who told us more about the strategy, as well as about the results of the Joint Undertaking's third call for proposals.

Mr. Krein, the ARIS strategy is backed by close to 100 aviation stakeholders and was handed over to the European Commissioner for Sustainable Transport and Tourism, Apostolos Tzitzikostas, at the Paris Airshow in June this year. What made this strategy necessary?

The EU aviation sector currently enjoys global technological leadership in several key areas, but this leadership position is not guaranteed. Europe needs to act decisively to secure its long-term competitiveness, particularly with regard to ensuring the sustainability and the sovereignty of the EU.

ARIS, the Aviation Research & Innovation Strategy, was developed to address these very aspects. The importance of ensuring EU sovereignty and sustainability is clear if we look at it in the context of the European aviation sector, a sector which generates 15 million jobs in Europe and contributes EUR 1.1 trillion to the European economy. Let's not neglect to mention that Europe currently accounts for 58% of the global market share in new civil aircraft, and that 70% of global airspace is managed by European air traffic management (ATM) technologies.

Aviation is obviously an important contributor to the EU economy, let's do our utmost to ensure it stays that way!

What are the challenges?

Countries like the US, China and India are investing heavily, and aviation feels the impact of both technological shifts and growing geopolitical complexity. We need to make significant investments in Europe if we want to maintain our technological edge and stay a frontrunner in sustainable technologies. A major concern is that promising technologies are not getting enough funding to reach entry-to-market status – they fall into the so-called "valley of death".

What solutions does ARIS propose?

ARIS emphasizes that the EU, Member States and the private sector need to join forces to develop a common strategic roadmap, and ramp up investment, in both Research & Innovation and support to market uptake: the strategy calculates that a total investment of EUR 66 billion is needed for the 2028-2034 period, which is the timeframe of the EU's next long-term budget. EUR 22.5 billion would be required at EU level, with the remainder to be funded by Member States and the private sector.

> "Countries like the US, China and India are investing heavily, and aviation feels the impact of both technological shifts and growing geopolitical complexity."

That's a substantial amount of money – how should it be spent?

I agree, it is a large sum, but it has to be seen in relation to the challenges, which are, as I've explained, both significant and urgent.

ARIS specifies three main areas where major investments are needed: next-generation aircraft technologies, efficient air traffic management and what the strategy calls "transforming enablers" – these are transversal topics such as improving manufacturing and maintenance, supporting digitalisation, and training workers to acquire new skills. ARIS stresses that all parts of the innovation pipeline are essential, from early-stage research to industrialisation and deployment.

Clean Aviation co-funds research into more sustainability in aircraft technologies. What, in your opinion, are the most promising ones?

I strongly believe that we shouldn't focus on just one technology. At Clean Aviation, we are prioritising technologies focusing on new propulsion systems, aerodynamic and structural improvements. The benefits of these technologies at aircraft level are being evaluated on three different aircraft concepts: ultra-efficient regional aircraft, hydrogen-powered aircraft and ultra-efficient short & medium range aircraft.

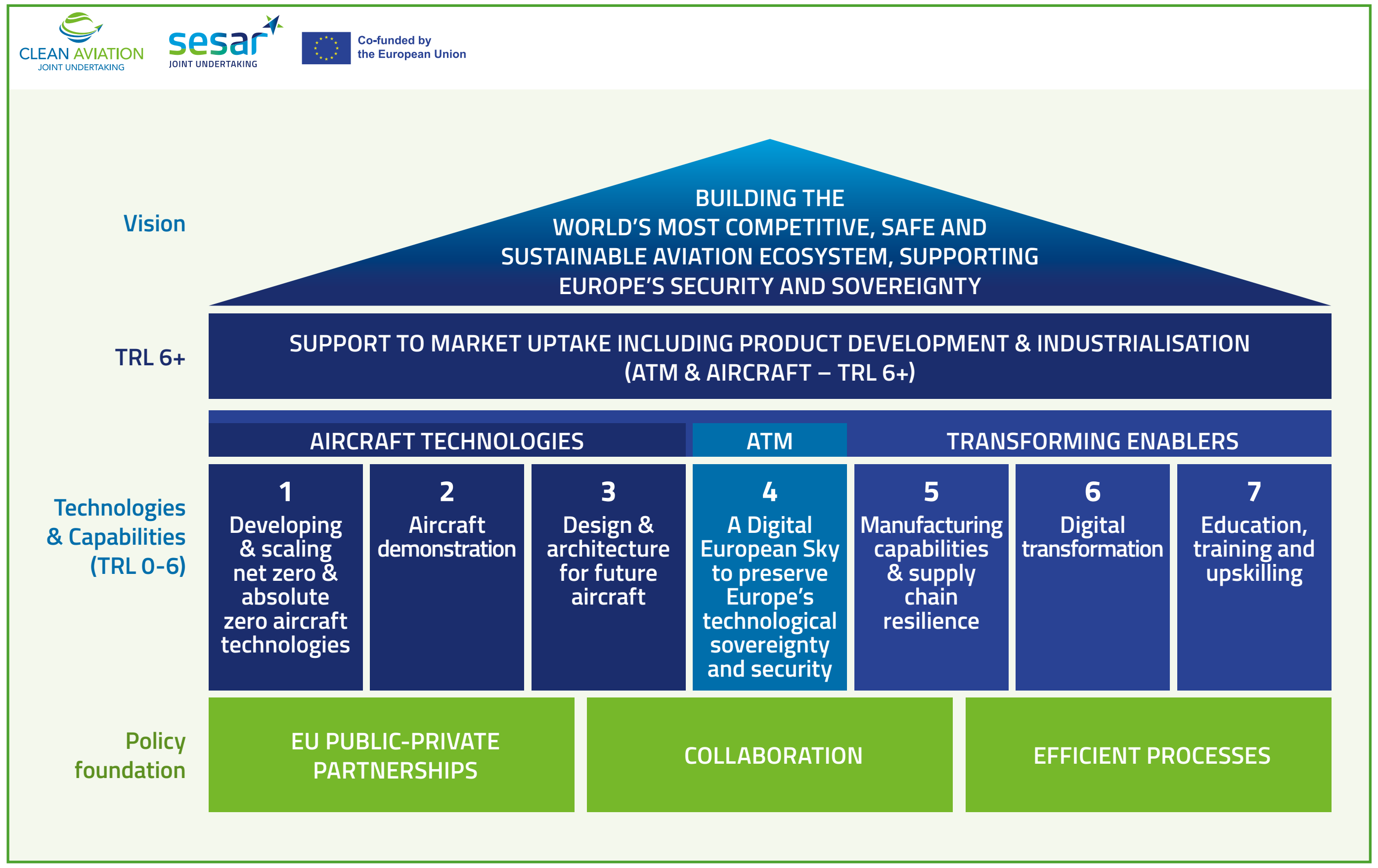
Our goal is to greatly reduce net greenhouse gas emissions for commercial air travel, and to pave the way for cleaner aircraft to start flying the skies by 2035. In our latest call for proposals, we selected 12 new innovative projects for funding. They will receive €363 million of EU funding. Together with the contribution of the private project partners, this represents an investment of €945 million.

To support the three aircraft concepts, we also have so-called "Fast Track Areas" which are accelerating essential new technologies into development. Projects in these fields are mainly carried out by start-ups, SMEs, academia and research centres.

One last question before we wrap up: Is a competitive yet sustainable aviation sector a realistic goal for the future?

I am convinced that if we are able to align the European public and the private sectors towards common objectives, we will succeed in making European aviation competitive and sustainable.

Let me use a simple example: in aviation, fuel accounts for roughly one third of airline operating costs. Increasing efficiency therefore means cutting costs, and we can achieve this thanks to advanced and disruptive technologies. If Europe can lead in innovative and sustainable aviation solutions, we won't just reduce emissions – we'll also strengthen our industrial base, create skilled jobs, and unlock new export opportunities. By doing so, this shift will make us less dependent on fossil fuels and increase Europe's strategic resilience. In short: it's a win-win! ■



> "A major concern is that promising technologies are not getting enough funding to reach entry-to-market status – they fall into the so-called 'valley of death'"

About Clean Aviation

The Clean Aviation Joint Undertaking is the European Union's leading research and innovation programme for transforming aviation and leading it towards a sustainable and climate-neutral future. It is a European public-private partnership with contributors from academia and research organisations to start-ups, SMEs and bigger industrial entities. The programme's disruptive clean aviation technologies will help reduce CO_2 emissions of short-medium range and regional aircraft by 30% as outlined in its Strategic Research and Innovation Agenda. Together with sustainable fuels, this will lead to a reduction of CO_2 emissions of future aircraft of approx. 90%.

www.clean-aviation.eu

News in Brief

Photo: Antony Whittaker

Crypto-tidal island

The island of Alderney, in the Bailiwick of Guernsey just off the coast of Normandy, is mulling an economic future powered by tidal energy and bitcoin mining. Leaders of the tiny self-governing British Crown Dependency, which has a population of around 2,000 and an average age of 58, want to diversify its economy away from online gambling, which has contributed significantly to its modest treasury for 25 years.

Alderney Race (*Raz Blanchard* in French) is a famously turbulent strait with strong tidal currents of up to 5m/s and, according to the Royal Society, the largest tidal-stream energy potential in north-western European coastal seas; some estimates put this at up to 5GW. Bitcoin mining – which involves solving computationally costly problems at a vast scale – is energy-intensive and dominated by large-scale facilities consuming hundreds of megawatts for each bitcoin earned.

Photo: Nuno Marques

PV gigafactory planned

French company HoloSolis has raised €220m for a photovoltaic module gigafactory in Lorraine, expected to be Europe's largest. The facility, which is to be built near the towns of Hambach and Sarreguemines, near the border with Germany, is due for completion in 2030 and could produce up to 5GW of cells and modules per year. CEO Bertrand Lecacheux said that HoloSolis already had 20GW worth of customer letters of intent.

"HoloSolis already had strong partners [in] InnoEnergy, Armor Group, IDEC, TSE, and Heraeus," he said. "We will be able to benefit from their expertise to build the largest TOPCon cell and module gigafactory in Europe.

For insights into India's photovoltaic manufacturing industry, and what it could mean for Europe's renewable energy sector, turn to page 42 for a short analysis by *EEI* writer Xiaoying You.

Photo: Stella de Smit

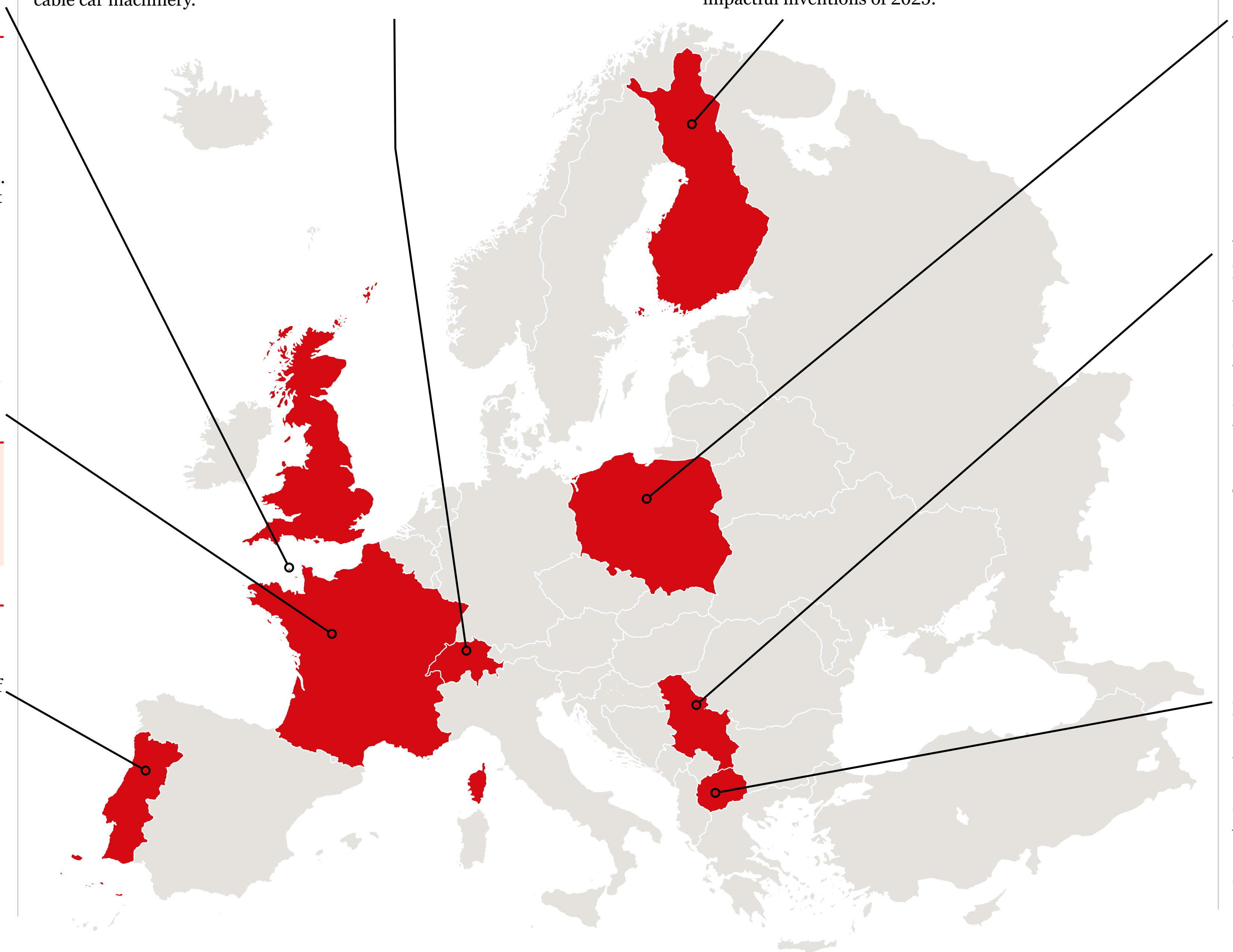
Heineken heat battery

Heineken's Vialonga Brewery near Lisbon will become one of the first large-scale users of an innovative heat battery, which will help generate the steam needed to brew Europe's most popular lager. The 100MW system from Rondo Energy will be fuelled using a grid connection and a 7MW on-site solar installation, and will be installed by EDP. The machine is expected to go live in 2027 and will be among the largest such systems in use in the beverage industry.

Folding solar record

A record-breaking 20,000 square metre, 3MW folding photovoltaic roof has been installed over a wastewater treatment plant near Thun, Switzerland, serving as both a multifunctional canopy and significant contributor of renewable energy. Its concertina design can be safely retracted or deployed depending on weather using a concertina mechanism on cables. The system is expected to produce up to 3.4GWh annually without competing for land with agriculture, industry or housing – a key consideration in Alpine areas. In addition to the photovoltaic panels, the lightweight, cable-supported structure uses half as much material compared with conventional rigid steel truss systems.

The system, called Horizon, has been developed by Swiss firm 'dhp technology' and is said to be inspired by cable car machinery.



2MW sand battery plans

Following the successful launch of the world's largest sand battery in Pornainen, Finnish energy storage company Polar Night Energy – which makes soapstone thermal storage systems – has unveiled plans to beat its own record. The new site, in Vääksy, about 130km north of Helsinki, will provide 2MW of thermal output and 250MW of storage capacity. That's twice the power and over twice the size of the previous site, and is expected to lower the emissions of the town's heating by almost two thirds.

The Pornainen installation has proven reliable. It contains 2,000 tons of crushed soapstone in a large silo-shaped vessel, and its optimisation system is managed by Finnish telecoms company Elisa, formerly Radiolinja. Finland's sand batteries were recognised by Time magazine as one of the 300 most impactful inventions of 2025.

Photo: Sigmund

Grid calls in the army

The armed forces of Poland will work alongside grid operator PSE to protect critical infrastructure such as transmission lines and transformers, following a series of sabotage attacks on energy and transport systems. The wave of sabotage, arson and explosions has been attributed to Russia by the Polish government.

"Besides critical nodes it's a matter of our place in Europe and the fact that Poland links the Baltic system with the rest of the continent," said Grzegorz Onichimowski, chief executive of PSE. "This part of our infrastructure requires particular attention."

Recent drone incursions blamed on Russia have highlighted vulnerabilities in Poland's transmission network. PSE is expected to receive anti-drone defences as part of the agreement with the army.

Photo: Stefan Kostic

Lithium mine halted

Rio Tinto has shelved its plans for a lithium mine in Jadar, Serbia, citing high costs and difficulty with permits. Its proposals for the site were subject to concerted backlash from environmental and community campaigners, and became a focus for popular movements in a country beset by political unrest.

The Jadar mine, which would also have extracted boron, had been included by the European Commission in its list of 13 strategic raw materials projects outside the EU. The deposit is estimated to contain over 100 million tonnes of jadarite, which contains both lithium and boron in relatively high concentrations, and it is one of the largest known lithium sites in the world. It encountered increasing cost projections and two decades' worth of political hurdles, community opposition, environmental scrutiny and intense political opposition.

Growing by 1MW a day

North Macedonia has been quietly adding an average of 1MW of renewable capacity per day, according to figures from the ERC.

Some 1,200MW of clean energy generation has been added since 2022, including photovoltaic sites. Solar accounts for 28 percent of generation capacity in the country, which has a population of 1.8m.

"For the first time in our history, solar has overtaken hydro, a symbolic and practical milestone in our path toward decarbonization," said Sanja Božinovska, Minister of Energy, Mining and Mineral Resources, according to *Balkan Energy News*. Hydropower accounts for 24 percent of the country's electricity.

North Macedonia recently issued its first licences for BESS installations, with two small sites planned totalling 2.6MW.

News in Brief

Shadow of drought

"Hydropower Is Getting Less Reliable as the World Needs More Energy," boomed a *New York Times* headline in November.

It's certainly true that drought in Europe is hampering generation, with Serbia's EPS expecting to record the lowest hydropower output in the company's history, Engie reporting a 18 percent drop in Q3 earnings due partly to limited rainfall in France, and Romania's Hidroelectrica anticipating record low production.

Most involved in hydroelectric generation and storage around the world, but particularly in states reliant on drought-hit regions, are sounding the alarm over hydrological stress, dry weather and low reservoir levels, the combination of which some analysts are framing as a long-term risk to the sector.

Meanwhile, Eurelectric and the International Hydropower Association (IHA) have launched the "Paris Pledge" in support of long-duration pumped storage.

Signatories call on national and state policymakers to enhance regulatory support to "unlock" 35GW of capacity in the EU, with specific calls to streamline permitting processes and introduce new financial instruments that de-risk investment.

In 2024, "exceptional rainfall" contributed to a record 680TWh in Europe, according to the IHA.

Negative light

All that sun has annoyed solar farmers, too. Producers across Europe have reported record periods of negative pricing, undermining profitability and worrying analysts. The Netherlands, Spain, Sweden, Germany, Belgium and France all logged over 500 hours of negative wholesale prices in 2025, with the *Financial Times* reporting disquiet among investors over the "seemingly perverse" market dynamics of European renewable energy.

In addition to the worst-affected countries, almost every EU member recorded negative hours in 2025. According to Eurelectric's 2025 Power Barometer, negative prices occurred in 4.5 percent of hours across the EU, up from 0.5 percent in 2019. In addition to excess renewable energy produced during favourable weather conditions, contributory factors include non-market-reactive prosumers (such as households with PV installations and fixed feed-in tariffs) and inflexible non-renewable generation (like plants connected with district heating systems, or lignite stations with high stop-start costs).

Grid-scale storage and long-distance transmission lines are two of the more prominent solutions to the phenomenon of negative wholesale pricing, though researchers suggest that projected increases in electricity demand could help "solve" the problem by 2035.

Tall timbers

Modvion AB, a Swedish company building wooden wind turbine towers, has been selected by the European Commission to receieve a significant grant to advance series production of its innovative timber structures, which offer environmental and practical advantages over steel.

Having already built a 103m tower in Skara in 2023, the Gothenburg-based firm obtained TÜV SÜD certification for its 119m design in 2025. It builds its towers from laminated veneer lumber in 15m long modules which are transported to the construction site individually, rather than as one annoyingly long and cumbersome steel unit.

The segments are then glued together, which is another advantage over steel; as the Modvion marketing text puts it, "imagine 50,000 steel bolts you don't have to inspect". The company estimates that swapping steel for wood reduces carbon dioxide emissions by 30 percent and tips the turbine's scale into carbon neutrality.

"The Innovation Fund grant will enable Modvion to scale production capacity to meet the demand from the European wind industry," said Modvion CEO Maria-Lina Hedlund.

"Our towers enable taller wind turbines to increase the efficiency and profitability of wind energy, all while replacing hard-to-abate steel and concrete."

Long waves

The longevity of tidal range energy stations was highlighted at the UK's Institution of Civil Engineers' Autumn Prestige Debate, where Severn Estuary Commission chair Dr Andrew Garrad CBE said that tidal range power installations would "last longer than a lifetime" and that planners "should be expecting 120 years" of service, which offsets the high upfront costs. Dr Garrad also highlighted that the technology was well-understood, well-tested and that the very long asset life made it difficult to adequately compare against other energy sources in financial terms.

These comments come in the wake of news that, in 40m of water off the coast of Scotland, a 1.5MW turbine in the MeyGen array had been running solidly for six-and-a-half years without unplanned or disruptive maintenance, a current record. According to Swedish engineering firm SKF, the world's largest bearing manufacturer, its systems have operated at 1.5MW since 2018, representing a new reliability benchmark. SKF has partnered with UK company Proteus Marine Renewables to expand the MeyGen pilot to 59MW.

Research published by the University of Edinburgh in September calculated that depending on supply chains and rate of deployment, the economic benefit to Europe of operating tidal stream projects in Europe could be between €15bn and €46.5bn.

Editor's note

This magazine is a longstanding dissemination and communication partner for Europe's energy researchers. And that's always been great news for our readers.

By **Ed Wiseman**, *EEI* editor

Perhaps the most interesting part of my role as editor of this magazine is reading the varied and often remarkable work submitted to us by members of the research community. While relatively short articles such as the three you are about to encounter deliver pithy, insightful introductions to their respective subjects rather than full in-depth accounts, they sow a seed in the mind of the reader that can be nourished – and potentially germinate into genuine understanding.

European Energy Innovation has a diverse subscriber base, united ostensibly by a commitment to Europe's green transition, or by a professional interest EU energy R&I. Most of the people on the digital and physical mailing lists are in research, policy, industry, corporate leadership or comms. But having chatted to readers quite extensively since joining the title in 2024, it strikes me that the main commonality is that sense of curiosity, and a desire to learn about the many small, iterative developments occurring in adjacent fields.

I wrote in this issue's foreword that I have been flicking through *EEI*'s back catalogue. Research has been part of the magazine's focus since the very beginning, with institutions and consortia choosing *EEI* to share their progress and to disseminate the activities of their projects from Issue 1, sixty quarters ago. While the world has changed enormously since 2010 (those early articles often included scientists' fax numbers) communicating energy R&I progress remains a priority for anyone involved in it.

That's tremendous news for me, our digital subscribers, our print subscribers and the thousands of ad-hoc readers who pick up their copies of *EEI* from libraries, institutions and events across Europe. Because alongside its contributors, *EEI* owes its existence to their enduring sense of curiosity, and desire to understand what's happening in worlds besides their own. ■

HiPE - High performance power electronics integrations

Developing efficient, compact and reliable WBG-based power electronics for mobility, to facilitate more significant market penetration of WBG in the automotive sector.

A European collaboration for advanced power electronics

The HiPE project (High Performance Power Electronics Integrations) brings together 13 partners from across Europe, combining industrial and research expertise along the automotive supply chain. The goal: to develop a new family of highly efficient, cost-effective, compact, and modular power electronics based on Wide Bandgap (WBG) technology.

HiPE's main objectives include improving energy efficiency by reducing power losses and cooling needs, cutting system cost and weight, and enhancing reliability through integrated design and intelligent control. The project focuses on scalable solutions applicable across vehicle platforms, from compact e-mobility to high-performance automotive systems.

Reimagining power semiconductors

Power transistors are at the heart of modern energy conversion. The HiPE review analyses how the industry is shifting from traditional silicon (Si) to Wide Bandgap materials such as Silicon Carbide (SiC) and Gallium Nitride (GaN).

Silicon Carbide (SiC) stands out for its high thermal conductivity and strong electric field resistance, enabling reliable operation at temperatures up to 200 °C. It reduces both switching and conduction losses, supporting smaller and lighter inverter systems. Although more costly than silicon, SiC's superior efficiency and reduced cooling demand make it the preferred choice for demanding automotive applications.

Gallium Nitride (GaN), by contrast, provides exceptionally high electron mobility and switching speed. Its High-Electron-Mobility Transistor (HEMT) structure allows MHz-range operation and ultra-fast switching. GaN devices are ideal where compactness and high frequency matter most, though their lateral architecture limits high-current capability compared to SiC. Together, these materials complement each other: SiC for high-voltage and thermal robustness, GaN for high-frequency, lightweight systems.

HiPE's comparative data show SiC offers superior temperature stability, while GaN still faces variability as manufacturing matures. True efficiency improvements require system-level optimization, balancing inverter, motor, and battery efficiencies rather than maximizing any single component.

Gate drivers: precision at the core

The gate driver controls the timing and strength of each transistor's switching event. As HiPE outlines, it directly determines efficiency, reliability, and electromagnetic compatibility.

For WBG devices, precise gate voltage control is essential. SiC and GaN components operate within narrower safety margins, demanding drivers with advanced features such as:

- Multi-stage switching for controlled transitions
- Active Miller Clamps to prevent unwanted turn-on
- Short-circuit protection and under-voltage lockout

Integrated gate-driver solutions also help minimize parasitic inductances and capacitances, improving switching quality and reducing overshoot and ringing. Embedding the driver near or within the power module is key to the next generation of compact, efficient inverter designs.

Packaging and thermal management

Reliable power electronics depend on efficient heat extraction and low electrical parasitics. HiPE compared several substrate and packaging technologies:

- Printed Circuit Boards (PCB): low cost but thermally limited.
- Insulated Metal Substrates (IMS): cost-effective for low- to mid-power systems.
- Ceramic substrates: excellent thermal match to silicon and superior insulation for high-power modules.
- Direct Bonded Copper (DBC) and Active Metal Brazing (AMB): combine ceramic cores with copper layers, ensuring mechanical stability and high thermal performance.
- PCB embedding: integrates components directly into the substrate, reducing parasitics and assembly steps.

Each solution represents a balance between thermal efficiency, mechanical strength, and cost. Advanced materials like aluminium nitride and innovative packaging (e.g., copper clips, dual-sided cooling) enable the next leap in power module compactness and reliability.

Outlook: towards integrated power systems

The HiPE project's comprehensive review underscores a key message: Integration across materials, gate drivers, and packaging is the pathway to next-generation high-performance power electronics.

By merging the strengths of SiC and GaN with optimized driver circuits and advanced substrates, HiPE paves the way for smaller, lighter, and more efficient systems that meet the rigorous standards of modern electric mobility.

As Europe accelerates toward a sustainable transportation future, HiPE's technological foundations ensure that efficiency, reliability, and innovation remain at the core of power electronics design. ■

About HiPE

The **HiPE project** is part of the EU Call "HORIZON-CL5-2021-D5-01-02. Nextgen vehicles: Nextgen EV components: Integration of advanced power electronics and associated controls (2ZERO)".

Funded by the European Union

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SCARLET – Superconducting cables for sustainable energy transition

SCARLET develops and industrially manufactures superconducting cable systems at the gigawatt level

The rising worldwide demand for efficient and sustainable energy transmission has renewed interest in high-power transmission technologies. Among these, superconducting cables represent a transformative solution: their ability to transmit large amounts of power with minimal losses in compact geometries makes them particularly attractive for urban environments, long-distance interconnections as well as offshore wind power export.

The EU project SCARLET takes advantage of the high current capability of superconductors to operate the cables at medium voltage (from 25 to 100 kVDC) in direct current (DC), while still maintaining multi-gigawatt transmission powers. These operation voltages reduce the footprint of substations and platforms, opening the door for cost savings beyond the cables themselves. In SCARLET, two demonstrators are being built: one based on high-temperature superconducting tapes and the second based on magnesium diboride wires. The latter offers the distinctive advantage of being operated in synergy with liquid hydrogen transport, thus enabling an integrated infrastructure that can simultaneously foster renewable energy sources and hydrogen-based energy systems. This approach is beneficial for green transportation systems and energy-intensive industries, where high amounts of both electrical and chemical energy are required. The timing is also auspicious, given the recent worldwide interest and investment in green hydrogen technologies.

Moreover, SCARLET investigates offshore superconducting cables, which present a potential impact even higher than onshore applications. The benefits of using such subsea systems are clearly linked to the intensive development of large wind farms located far offshore. Most of the technology bricks available from onshore cable system applications are directly transferable to subsea applications. One of the main technical challenges is the adaptation of the cryogenic envelopes surrounding the superconducting cables, which must withstand the outer water pressure and various dynamic mechanical loads. Another challenge is the management of the cooling technology over very long offshore distances. The SCARLET studies show that it is possible to have 80 km of subsea cable without intermediate offshore substations, which is a very promising premise for deployment.

Of essential importance is the strategy for integrating and protecting such a gigawatt superconducting system and the electricity grid. This involves analysing the technical requirements and key components of the electrical system in which the cable is integrated. One case of particular interest is the power export from gigawatt-scale offshore wind farms, which today uses high-voltage DC export cables and requires a large offshore conversion platform. Here, using medium-voltage superconducting cables offers the possibility to eliminate the offshore converter on the wind power collection platform, resulting in significant simplification and cost reduction. Hence, SCARLET also includes system-optimisation and techno-economic assessments, to confirm the beneficial application areas and advance the exploitation paths of the investigated technologies. In the comparison between superconducting and resistive cable systems, a holistic approach is applied considering, in addition to the cables themselves, the benefit of operation at lower voltages offered by superconductivity.

As a concrete grid protection device, the project partners designed a fault current limiter rated for 10 kADC and 50 kVDC, the same operation values as the SCARLET superconducting cables. The fault current limiter is a key protection element that needs to carry the same load current as the transmission cable. Typically, such grid elements are rated for 2 kADC, therefore SCARLET is advancing innovative development in this area, as well. The proposed solution uses a superconducting fault current limiter, which exploits the ability of superconducting materials to rapidly switch from the perfectly conducting state to the resistive state, based on the instantaneous current value. Hence, if the operating current exceeds a threshold value in case of a grid fault, the conductor becomes almost instantaneously resistive. Combined with an inexpensive medium-voltage DC circuit breaker, this limits the current and ensures the continuity of grid operation, while also reducing the size of protection equipment on the ground by 40-50%. As a world-first proof of concept, a successful testing campaign at 50 kV took place at the beginning of the year, and the SCARLET fault current demonstrator is currently being assembled.

The power supply system is critical infrastructure, and the risk of failures and outages must be kept to an absolute minimum. In addition, it must be ensured that new components do not pose risks to the environment or to maintenance personnel. This requires thorough testing and qualification of new technology. The testing protocols used for qualifying the SCARLET demonstrators will be shared with relevant working groups and standardisation bodies such as Cigré, IEEE and IEC, which will contribute to advancing the standardisation framework for superconducting cables. ■

About SCARLET

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NICHOLHy – Novel insulation concepts for liquefied hydrogen storage tanks

Thermal Insulations for the Economic and Safe Large-Scale Storage of Liquefied Hydrogen

Europe's transition in energy imports and storage faces a critical challenge: how can hydrogen be stored and transported safely and efficiently on a large scale? While pipelines and geological storage for gaseous hydrogen are only partially available, liquid hydrogen (LH_2) is increasingly coming into focus. With its high volumetric energy density, LH_2 is the preferred solution for international transport by ship—and could revolutionize the global transport of energy.

Why Liquid Hydrogen?

Among the Hydrogen derivatives, LH_2 offers decisive advantages. It is extremely clean, requires no chemical conversion processes, which offers high process chain efficiency as well as reliability, is non-toxic, and probably enables the use of existing liquified natural gas (LNG) infrastructure. This makes LH_2 a key contributor to Europe's energy supply security. However, one major obstacle remains: large-scale LH_2 storage tanks do not yet exist, and current technologies are difficult to scale and costly.

The Solution

LH_2 and LNG are stored at different temperatures, namely at minus 253°C and minus 161°C, which does not allow direct transfer of insulation techniques in transport and stationary tanks. This is where the EU-funded **NICOLHy** project comes in. Researchers from BAM (DE), Uni Bologna (IT), DLR (DE), NTNU (NO), and NTUA (GR) are developing a novel insulation concept based on Vacuum Insulation Panels (VIP). This technology aims to make the production of large LH_2 tanks not only safer but also significantly more cost-efficient. The vision: storage capacities ranging from 40,000 to 200,000m³ – comparable to today's LNG facilities.

Innovation Through Vacuum Insulation Panels (VIPs)

VIPs are at the heart of this new approach. VIPs are based on a fill material with a vacuum that is enclosed by a gas-tight envelope in the form of a membrane. This combination improves thermal performance, e.g., compared to thermos bottles.

Exemplary VIPs can have dimensions of 1m x 1m in length and width, by a thickness of 0.1m, and can be manufactured with application-dependent dimensions. Furthermore, VIPs achieve lifetimes of 10 to 100 years, depending on the choice of fill material and envelope. VIPs are standardizable, mass-produced products that involve a highly automated prefabrication process and very high-quality assurance, which can be achieved in an industrial environment.

The principle of VIP enables changing the current shape of large LH_2 tanks from spherical to prismatic, which offers up to 65% higher storage capacities, for instance on ships. Furthermore, the VIP principle reduces the production time of tanks, while the mass of VIPs makes them simple and fast to install, and redundant and safe. Today, VIPs are used in refrigerators, as packaging material, as well as in houses. However, for use under extreme conditions like LH_2, several questions remain: How will the material withstand thermal stress? How can we mount and install it?

NICOLHy progress

NICOLHy addresses the complex challenge of LH_2 storage by examining both large-scale tank design and detailed insulation aspects. A comprehensive design study, supported by literature reviews and interdisciplinary workshops, led to twenty-four conceptual variants. These were evaluated for safety, scalability, and sustainability, and will be benchmarked throughout the projectby Key Performance Indicators defined in the project as well as the Strategic Research and Innovation Agenda from the European Clean Hydrogen Joint Undertaking.

For the evaluation of the VIP based concepts, numerical models and databases are being developed, including material combinations, spatial configurations, geometries, dimensions, and mounting principles, as well as their circularity and economic viability, and safety. The most promising concepts will be tested and evaluated using a large-scale test rig that will go into operation in 2026. The most important aspects of these tests are the examination of installation procedures, the testing of the mechanical behaviour of stacked VIPs and other configurations, and the examination of the consequences of an accident, all under realistic conditions.

The activities and their prioritization are carried out in close cooperation with NICOLHy's Stakeholder Advisory Board (SAB), which includes representatives from political decision-makers, industry representatives, standardization bodies, research, and other projects. This cooperation ensures high quality, applicability, and acceptance of the results, as well as excellent transferability. The results of the NICOLHy project will promote global trade in LH_2 through cost-effective, efficient, and safe stationary tanks and ship tanks, as well as by supporting the development of recommendations, codes, and standards.

Conclusion

Initial results suggest that VIP-based insulation could revolutionize LH_2 storage, offering cost and time efficiencies while maintaining safety. Close collaboration of the NICOLHy consortium with industry and a stakeholder advisory board ensures practical relevance and supports standardization efforts. ■

About NICHOLHy

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On thin ice

Russia's invasion of Ukraine has critically damaged 'Arctic exceptionalism'. Europe must now prioritise the region in its plans for energy, innovation and security.

By **Zsanett Gréta Papp**

"While the Antarctic is an ice-covered continent surrounded by ocean, the Arctic is an ice-covered ocean surrounded by lands"

The Arctic has long held a unique position in the world's political consciousness. From the mid–20th century onward, it was treated less as a competitive frontier and more as a shared space of scientific discovery, cooperative governance, and Indigenous stewardship. Even during the Cold War, the so-called "Arctic exceptionalism" framework – the idea that geopolitical tensions stop at the Arctic Circle – held enough sway to keep academic, environmental, and even diplomatic channels open.

However, this era, which has been serving the Arctic countries and world for decades, now seems to be over. The Russian invasion of Ukraine in 2022 did not immediately send shockwaves through the Arctic's ice sheets or fjords, but it sent them reverberating through its institutions, research networks, security stakeholders and energy politics.

The decisions made – or avoided – there will carry consequences far beyond the region. As one of the leading analysts of Arctic geopolitics, Andreas Østhagen of the Fridtjof Nansen Institute, has argued: "The Arctic is often portrayed either as a battleground for great-power rivalry or as a zone of pure cooperation. In reality, it is neither."

The truth is, the Arctic is neither purely cooperative nor purely competitive – it is, in many ways, both at once. Far from being a political vacuum, it has become a strategic arena. As Europe grapples with the implications of the war for its energy transition, technological sovereignty, and competitiveness on the global stage, the Far North increasingly serves as a testing ground for these transformations.

As a geopolitical analyst, I was taught to always look at the map first, before drawing conclusions. When we do so, a striking difference emerges between the Arctic and the Antarctic: while the Antarctic is an ice-covered continent surrounded by ocean, the Arctic is an ice-covered ocean surrounded by lands, and that ice is melting four times faster than anywhere else on Earth.

This geographical and climatic contrast is not merely academic; it fundamentally shapes how both regions are governed, contested, and understood. As the Arctic itself undergoes dramatic change, so too does the testing ground that it represents. The Arctic is not just getting warmer, but also it is more fragmented, less governed, and more exposed to competition than ever before, inviting us to put the question: is this the "great cold war"?

A new era of EU Arctic policy

The European Union already recognised the shifting Arctic reality when it launched its revised Arctic Strategy in 2021. On paper, the EU aims to be a partner for climate resilience and sustainable development, to protect biodiversity, and – significantly – to accelerate the green transition in the region. What stood out was a clear political commitment: the EU will not support new fossil fuel extraction in the Arctic. But elsewhere in that very same document was direct reference to Europe's growing need for critical raw materials (CRMs), including rare earth elements essential for green technology, many of which are found in Arctic territories, such as Greenland or Canada.

The Arctic therefore seems to emerge as both "resource frontier" for the Arctic states, the non-or-near Arctic states and the EU - and as "renewables testing ground". European energy security and the path to climate neutrality hinge, perhaps ironically, on this fragile, climatically unstable region.

The communication has been becoming more articulated since 2024, which is also a milestone in Greenlandic-EU relations, as the European Commission opened its EU Representation Office in Nuuk, Greenland's capital. Only a year later, on 27 October 2025 in Stockholm, European Commission President Ursula von der Leyen declared that the Arctic is no longer peripheral but central to Europe's strategic calculations. With the ice retreating faster than anywhere else and new shipping routes opening, the EU is now revising its Arctic policy and doubling its partnership with Greenland to secure raw materials and strengthen its High North footprint. She also announced that the EU is in the process of revising its Arctic policy released in 2021, to respond to the new realities of strategic competition, climate change, and resource pressure. Earlier, on 2 October 2025, the Commission announced it intends to double its financial support to Greenland, citing the island's strategic importance for Europe's green transition and security.


An early-warning radar station in Norway

"Greenland needs the European Union, and the European Union needs Greenland."

These statements signal a policy pivot. Europe is accepting that the Arctic is not only a climate frontier but also a strategic zone of competition and resource access. The Greenland support move ties directly into the "critical materials" narrative developing around the Arctic.

In his landmark address to the European Parliament on 8 October 2025, Greenland's Prime Minister Jens-Frederik Nielsen told MEPs that "Greenland needs the European Union, and the European Union needs Greenland." He placed the island squarely within the European strategic calculus – noting that Greenland holds 24 of the 34 critical raw materials identified by the EU, and urging investment in mining, hydropower and digital infrastructure as part of the bloc's green transition. At the same time, he emphasised that partnership must rest on shared values of cooperation, equality and respect.

The war in Ukraine accelerated Europe's energy transition, but it has also complicated that transition in terms of raw materials extraction, clean tech manufacturing, and northern grid expansion.

Three energy priorities intersect with Arctic policy today:

Critical minerals for clean tech: Greenland, northern Sweden, and Norway hold essential deposits of cobalt, graphite, nickel, and rare earths. Securing sustainable access to these supplies is now framed as a strategic priority.

Cold-climate testing for renewables and hydrogen: The Arctic is becoming a testbed for offshore green hydrogen, low-temperature material science, and grid resilience projects.

Decarbonised maritime routes: The Northern Sea Route and trans-polar shipping may shorten supply chains between Europe and Asia – but also raise emissions and security risks if not carefully regulated.

These are not abstract scenarios. The EU's Critical Raw Materials Act and Net-Zero Industry Act, both introduced in 2023, explicitly mention Arctic extraction and Arctic research as opportunities – and risks. If "strategic autonomy" is the new watchword of Brussels, then the Arctic is where energy policy, foreign policy, and industrial policy meet on thin ice.

War in the High North

Before the Russo-Ukrainian war, the strategic balance between green ambition and resource dependence could be mediated through broad scientific cooperations and low-intensity or in other terms "silent" diplomacy. Today, it is mainly mediated by geopolitical rupture. Russia controls roughly half of the Arctic's coastline and is home to most of the permanent Arctic military infrastructure, major fossil fuel deposits and other, mainly mineral, resources. The water alongside the Russian coastline enables a new shipping route serving both economic and military purposes – the so-called Northern Sea Route – which is becoming more accessible due to climate change.

While before 2022, European institutions – including research networks and environmental monitoring platforms – relied on at least a limited ability to collaborate with Russian partners, the navigation of this alternative shipping route has become an exclusive project deepening the economic cooperation between Russia and China.

Most projects with Russian partners funded by the EU or its Member States were halted or legally unable to continue. Russia's participation in intergovernmental bodies such as the Barents Euro-Arctic Council was suspended indefinitely. The Arctic Council, which has been serving as the cornerstone of the Arctic governance as the central intergovernmental forum since 1996, continues to exist formally, but functions only in a de facto fragmented state, with Russia being unable to engage actively with the seven other Arctic states. This has caused a double shock to Arctic governance.

The regional forums and working groups have ceased operating normally. The climate and permafrost monitoring projects have lost access to key Russian data. And the Arctic LNG, new mining projects, and shipping routes became subject to Western sanctions, security evaluations, and strategic decoupling.

Just as troubling is the loss of long-term environmental knowledge: many of the measurement stations in northern Siberia, Chukotka, and the Laptev Sea are now inaccessible to Western

Opinion

A Canadian aircraft patrols the Northwest Passage

researchers. That includes crucial methane flux stations and permafrost research zones, in a region with the highest potential contribution to abrupt climate change. Arctic science, and by extension Europe's ability to forecast risk, has become a casualty of war.

What's left of Arctic innovation?

Although cooperation with Russia has ceased, Arctic research has not. Instead, it is being reconfigured – both institutionally and geographically.

Several European-led consortia, including EU PolarNet, Svalbard Integrated Arctic Earth Observing System (SIOS), and Norway-led High North research clusters, have moved to reinforce cooperation between Greenland, Iceland, Canada, the Nordic countries, and the EU's own polar institutes.

At the same time, the political vacuum created by the war is spurring new initiatives; alongside intensified negotiations between the EU and Greenland on resource extraction, Norway is increasing investment in Arctic offshore wind, CCS and hydrogen, which are framed as climate solutions and economic drivers, and Finland and Estonia are collaborating to connect Baltic innovation hubs with Arctic data systems, including next-generation weather modelling.

But the shift has also exposed vulnerabilities. Without access to Russian territory, European researchers cannot independently track sea ice trends across the Siberian Arctic. Without a shared regulatory framework, investment in Arctic technologies – such as satellite monitoring or subsea fibre optic systems – is slowed by political uncertainty. And without trust-building mechanisms, the risk of militarisation or commercial overexploitation grows.

Six priorities for EU Arctic policy

The Arctic is no longer a zone of exception – but that does not mean it must become a zone of conflict. What it becomes next will depend largely on how Europe updates its approach.

Should the EU treat the Arctic only as a resource backend? Only as a geopolitical arena? Or is it still possible to treat it as a space where scientific integrity, climate commitments, and long-term cooperation based on the needs and knowledge of the local, indigenous communities, can shape the future? The answer will define not only Europe's Arctic policy, but Europe's credibility as a leader in the global green transition. The situation is not irreversible. Europe can and should:

1 Safeguard long-term Arctic research infrastructure

Europe must ensure that climate and environmental monitoring – especially in Greenland, Svalbard, and the European Arctic – continues without political disruption. This requires stable funding independent of short-term crisis cycles. The Arctic is one of the fastest-warming regions on Earth, heating at more than four times the global average. This makes long-term observation of its physical and ecological systems an existential necessity for global climate policy. Yet Arctic research infrastructure – from satellite data hubs to on-site climate observatories – is increasingly vulnerable to political shocks, budget fluctuations, and international tensions.

A robust approach would include multiannual EU funding frameworks, on a similar basis to how the European Space Agency insulates long-term missions from annual budgetary volatility and short-term crises. Sustained investment in shared data systems (like Copernicus and SIOS) is vital. It also means supporting logistical resilience: research stations, icebreakers, and satellite links should remain operational even under conditions of geopolitical disruption. Without such continuity, Europe risks losing decades of climate data just when it is most urgently needed for energy transition and adaptation planning.

2 Develop an integrated Arctic energy and innovation agenda

Europe's green transition cannot succeed without addressing its northern frontier. The EU and its Arctic Member States – Finland, Sweden, and Denmark (via Greenland) – must align their energy and innovation strategies to Arctic realities. These include extreme weather, logistical remoteness, and community-specific constraints on development. An integrated agenda would link renewable energy generation, hydrogen production, mineral extraction, and digital connectivity into a single strategic framework. For example, Finland's hydrogen valley projects, Sweden's fossil-free steel and battery production, and Greenland's rare earth mineral initiatives should not evolve in isolation but be coordinated through EU-level innovation clusters. Digitalisation – including Arctic broadband, data centres, and satellite-based systems – must also be part of this strategy, as Arctic connectivity is central to both research and clean-tech deployment.

Moreover, the Arctic's energy transition should explicitly include carbon management technologies (CCS, geothermal, offshore wind) designed for cold climates, helping Europe to test and export sustainable models to other extreme environments worldwide. This would position the EU not just as a consumer of Arctic innovation but as a global leader in climate technology for high-latitude regions.

3 Reinforce cooperation with non-Arctic and quasi-Arctic partners

While only eight nations are officially recognized as Arctic states, scientific and technological contributions to Arctic research come from across Europe. Countries such as Germany, France, the Netherlands, Poland and Italy maintain advanced polar institutes and research infrastructure but rely heavily on partnerships with Nordic and North American actors for fieldwork and data. The EU should strengthen these "quasi-Arctic" linkages through joint laboratories, research mobility schemes, and infrastructure-sharing agreements. Initiatives such as the European Polar Research Icebreaker Consortium (EPB) and the MOSAiC expedition model show how shared facilities can multiply capacity without duplicating costs.

A network-based model of Arctic cooperation could also mitigate the loss of Russian access: if European institutions pool logistics and technology – from icebreakers to supercomputers – they can maintain near-global coverage of Arctic observations. Finally, building stronger connections with transatlantic partners (Canada and the U.S.) through the Arctic Science Ministerial framework would reinforce Europe's position as a stable, collaborative pole in a fragmented Arctic order.

Russia still operates a mining settlement in Svalbard

4 Prioritise Indigenous knowledge and community consent

Indigenous-led research programmes must be part of any future research/investment framework. No sustainable Arctic policy can be legitimate without the full and informed participation of the people who live there. Across Greenland, Nunavut, northern Scandinavia, and Arctic Russia, Indigenous communities – including the Inuit, Sámi, Nenets, and Chukchi peoples – have millennia of ecological knowledge and deep social understanding of environmental change.

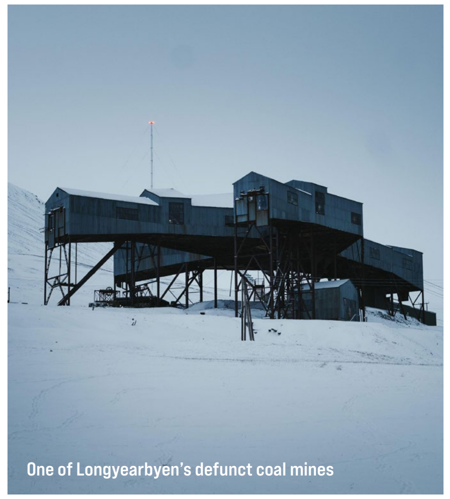
Europe's Arctic engagement must therefore shift from consultation to co-governance. This means embedding Indigenous-led research programs, creating formal positions for Indigenous representatives in EU Arctic forums, and ensuring Free, Prior and Informed Consent (FPIC) in all investment projects.

For example, any European-supported mining, energy, or infrastructure initiative should undergo cultural impact assessments in parallel with environmental ones. Beyond ethics, this approach improves scientific accuracy: Indigenous observations often provide earlier and finer-grained data on permafrost melt, biodiversity shifts, and coastal erosion than satellite imagery. Integrating Indigenous knowledge into European science systems can bridge local experience with global modelling, producing more grounded and just outcomes.

5 Prepare for institutional renewal beyond the Arctic Council

The Arctic Council, founded in 1996, has been the cornerstone of regional governance but since Russia's invasion of Ukraine its functionality has been severely constrained. The suspension of most cooperation with Moscow has left half the Arctic effectively unrepresented in scientific and policy discussions. This hiatus underscores the need for Europe to prepare alternative or complementary frameworks for dialogue and cooperation.

The EU could promote new science-diplomacy platforms capable of operating under geopolitical stress – flexible enough to function even when traditional diplomacy fails. Examples might include Arctic sub-councils led by non-state actors (universities, research consortia, Indigenous organisations) or thematic alliances focusing on energy, shipping, or biodiversity. Such institutional



One of Longyearbyen's defunct coal mines

innovation would not replace the Arctic Council but would sustain its spirit until full cooperation becomes possible again.

6 Put the Arctic in the forefront of the EU Science Diplomacy Framework

Science diplomacy – the use of research cooperation as a bridge in international relations – has always found its strongest expression in the Arctic. The region once allowed rivals to work side by side, producing shared climate data even during moments of global tension. That legacy must now be revived and modernised through the EU Science Diplomacy Framework. The European Commission's Global Approach to Research and Innovation (2021) and the European Research Area (ERA) Policy Agenda both identify science diplomacy as a tool of strategic autonomy. Yet they do not explicitly prioritise the Arctic. Europe should correct this by designating the Arctic as a flagship zone for its science diplomacy initiatives – a proving ground for how the EU integrates knowledge, climate, and foreign policy.

Concretely, this would mean creating an EU Arctic Science Diplomacy Platform under Horizon Europe or FP10, aligning research, innovation, and external action in one structure. It could coordinate mobility programs for Arctic researchers, ensure data-sharing continuity under international tension, and serve as a neutral bridge between Western, Asian, and Indigenous institutions. By bringing the Arctic into the heart of the EU's diplomatic and research agenda, Europe would reaffirm its identity as a cooperative power – one that leads not through domination, but through knowledge, partnership, and credibility. In a warming, divided world, that may be its strongest form of influence. ■

EEI Analysis

The lithium wars

Escalating global competition for control of lithium supply chains pose political, legal, technical and environmental challenges for European leaders

By **Sam Meadows,**
EEI journalist

"While several lithium deposits have been identified in Europe, most notably at a site in central Germany, commercial extraction has yet to begin."

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A decade ago Chinese officials designed a plan to dominate the world in several key sectors within a decade. Three years later they began to distance themselves from "Made in China 2025" in order to curry favour with their European and American counterparts. But the plan continued in the background, unabated.

That dominance is particularly evident in the supply chain for lithium batteries. Today, as a result of protectionist policies, strategic global expansions and a healthy dose of state funding, China dominates the market for electric vehicles and the cells which power them.

One of the most important components of an EV battery is lithium. The metal is so lightweight that it is ideal for power cells that need to be highly mobile, hence its dominance in transport and tech. Research into batteries using sodium is ongoing, but at present the weight advantage of lithium batteries makes them the preferred choice for vehicle manufacturers.

While Australia and Chile beat China into third place when it comes to lithium extraction, the vast majority of the unprocessed result is sent to China and does not emerge until it is in battery form – or even better, if you are the Chinese government, within an electric vehicle.

For Europe this creates a problem. Car manufacturing accounts for some six per cent of GDP across the 27 member states, and the continent is responsible for 25 per cent of EV sales. As European countries continue to pursue their goal of phasing out combustion engines by 2035, lithium batteries – and the components that make them – are only going to become more important.

If Europe fails to catch up – or at least take a chunk of that market share – then its significant automobile industry "risks becoming a thing of the past", researchers at Lund University in Sweden warned, as a result of dependence on Chinese industry.

The risks of this dependence came into stark focus in October, when Xi Jinping's government announced that foreign companies would need permission to export materials like lithium, giving China ultimate control over how they are used.

Lithium is fast becoming one of the world's most important minerals. Demand is expected to boom after 2030 as electric vehicles become central to our lives. But "artificially" low prices are hampering European efforts to catch up. The question now is: is it too late to do something about it?

At the start of the new millennium, China had barely any lithium mining or processing capacity. This was not unusual at the time. Only Chile, where extraction began in the 1980s, had much of an industrialised lithium footprint, with a few plants spotted elsewhere.

Today, China dominates. The Chinese government recognised the importance of a healthy lithium supply chain early on and, through a series of strategic overseas investments and state support, has catapulted its industry to success.

Chinese companies hold stakes in Greenbushes, the largest lithium mine in the world in Australia, and in the Chilean lithium giant SQM, wresting a minority stake away from the son-in-law of former Chilean dictator Augusto Pinochet. The Made in China 2025 plan designated electric vehicles as a key industry, and Chinese companies mine for the mineral at a loss in order to give its battery manufacturers a secure supply.

This has left Europe behind. Despite its hugely important car industry, Europe currently has very little in the way of refining or battery-making capacity. The Lund study warns that Europe currently has a larger supply deficit than the US and China.

This has created energy dependency. A 2025 German study warned that Europe suffers from an "indirect form of energy dependency" and that capacity will need to increase.

There's a risk of becoming "vulnerable to other people's whims" and losing strategic autonomy, said Luc Braun, an analyst at Benchmark Mineral Intelligence. "We've seen how big of a problem fossil fuel dependency is with Russia," he added. "It restricts your options."

This risk was crystalised in October when China's government announced that foreign companies would need its approval to export products containing rare earths, including lithium. It has said that products intended solely for civilian use will be unaffected, but analysts are concerned that this represents a significant risk for European carmakers.

André Månberger, the researcher behind the Lund study, said in a press release: "The risk of China's dominance is not only that Europe will lose its domestic automotive industry and thus its prosperity, but also that we could become a target for blackmail in the event of global conflicts."

Irina Patrahau, a critical minerals expert at the Hague Centre for Strategic Studies, said: "They're showing that they are willing and able to use [their dominant position], as leverage for other goals."

While several lithium deposits have been identified in Europe, most notably at a site in central Germany, commercial extraction has yet to begin. "We're still waiting for one project that shows that it is possible and give some confidence in the European environment," Patrahau said.

However, according to the Lund study – published before the German discovery – if existing lithium deposits were to be exploited, the EU could halve its future import dependence. "These projects could make up a big part of the total demand," Månberger said.

Central to the EU catch up play is the Critical Raw Materials Act, passed in 2024. According to the legislation, by 2030 the EU must mine 10 per cent of its annual needs, process 40 per cent and recycle 25 per cent. It also manages overseas reliance, stating that no more than 65 per cent of annual needs must come from a single country.

The Act has designated 47 projects as of strategic importance, 18 of which relate to lithium. Strategic designation means member states are required to ease the projects through the process of permissions and permitting.

However, critics point out that, while the designation of strategic importance means that the EU will link companies with private investors, it does not release any public funds to support development. "[The financing] is something we really feel they need to do more on," said Emily Ritchey, policy manager at the Brussels-based think tank Transport and Environment.

For Peter Tom Jones, director of the KU Leuven Institute for Sustainable Metals and Minerals, Europe is in need of a "paradigm shift" when it comes to lithium and EV production. "Made in Europe" supply chains are needed , along with public procurement schemes which incentivise buying European-made vehicles, buses and batteries. This would require supporting development across the whole supply chain. "If one step is missing, then the EU loses its autonomy. A chain is only as strong as its weakest link," he added.

The most promising discovery so far was made in September in Saxony Anhalt in central Germany. Neptune Energy announced that a deposit containing 43 million tonnes of lithium had been found. This would make it one of the largest deposits in the world, rivalling the entire Lithium Triangle of Argentina, Chile and Bolivia. Magazine *Interesting Engineering* claimed it could "transform Europe's role in the global EV and battery supply chain", while Neptune chief executive Andreas Scheck said the company could "contribute significantly" to the supply of lithium.

Other analysts were less sure that this discovery would transform the fortunes of the industry. The near-term significance of the discovery had been "exaggerated" according to Jones. "The average time between locating an economically viable deposit and producing lithium is around 15 years," he said. "Even if the new discovery is world-class, it's going to take a long time before it will have any effect." The EU needs to be supporting large companies which are ready to extract now, he added.

"It [the potential for less carbon intensive mining] is super exciting," Ritchey said. "We should be exploring this in a responsible way, but that doesn't mean we won't need to source lithium elsewhere."

The German project – like all of those within Europe – will have to overcome several challenges. Securing investment in an environment where lithium prices are low is perhaps the most pressing, but it will also need to find a way to square increased lithium mining and extraction with the green energy ambitions of the continent.

On the price side, lithium hit an all-time high in 2022 as EV demand soared. But an increase in supply has seen the price fall by roughly 80 per cent from its peak. Mines in Argentina are operating below capacity, even as dozens of new projects are being proposed.

Jones said the development of lithium capacity in Europe was being threatened by what he described as "geopolitically manipulated" prices, referring to China's practice of "flooding the market" with cheap, subsidised lithium. "Projects would run at a loss if they start up today," he explained.

This underlines the need for public investment in the industry. Chinese lithium producers mine at a loss, subsidised by regional governments who recognise its strategic importance further down the supply chain.

This leads to another issue that China breezes past far more easily than European companies could: the environmental impact of lithium mining. A 2024 article in the Lancet warned that the process for extracting lithium contains "considerable environmental risks", including pollution, ecosystem

“Chinese lithium producers mine at a loss, subsidised by regional governments who recognise its strategic importance further down the supply chain.”

destruction and intensive water use. “The challenge lies in balancing lithium’s role in a sustainable green energy future with the need to protect the environment,” it said.

China has proven far more relaxed about environmental regulations than the EU, giving it a competitive edge. However, this may not be as pronounced an issue as it is sometimes made out to be. The EU represents a huge global market, and Chinese companies will want to continue accessing it; European legislation mandating clean supply chains should have an impact on standards.

Ritchey said that Chinese battery and car manufacturers are making efforts to ensure they comply with EU regulations. “The EU can only go so far, but it can place requirements on products coming into the market which make those companies selling batteries in Europe responsible for addressing the supply chain impacts,” Ritchey said. “Chinese manufacturers are coming and asking how they can meet those requirements because they want to sell their cars in the market. So it’s a tool.”

However, some experts have said that while EU policymakers insist on high standards at home, they have been willing to turn a blind eye to supply chain issues elsewhere in pursuit of securing lithium supply. The Lithium Triangle currently supplies 85 per cent of the EU’s lithium imports. A 2024 study by the National Scientific and Technical Research Council of Argentina and other institutes said that: “The current EU responsible sourcing approach overlooks critical local-level justice considerations.” The researchers argued that in order for the EU to “ensure a just supply chain” it needs to prioritise issues like adequate consultation of indigenous people and equitable participation for communities.

In Chile, partly in response to the complaints of indigenous communities, Albemarle and SQM were made to renegotiate their licences to extract and obliged to share a small percentage of profits with local communities.


A protest against lithium mining in Belgrade in 2021

The EU has signed trade partnerships or memorandums of understanding with several lithium-producing countries, including Chile, Argentina, the Democratic Republic of Congo and Rwanda. Pia Marchegiani, of the Environment and Natural Resources Foundation, an Argentine NGO, said: “Some of these governments are weak in terms of the rule of law and democratic consensus, and they’re pushing to be a partner of the EU. The EU is willing to turn a blind eye on this.”

The Lithium Triangle

The intensive water usage the Lancet alludes to is a factor that has led to local opposition to lithium mining. When the plans for a lithium mine in the Jadar valley in Serbia were announced it sparked large protests. Activists warned of “irreversible environmental damage” if the plan went ahead and also baulked at the overseas involvement of Rio Tinto, which has since paused its plans citing permit delays. Villagers living near a proposed mine in Portugal have also protested over the potential use of water from a local river.

The use of water is a real issue. In Argentina, a community living close to a mine which opened in the 1990s claims that lithium extraction has caused the local river to “dry up”. A study from the University of Massachusetts found a reduction of 90 per cent in wetland vegetation after mining commenced. A Chilean study has also suggested that the Atacama Salt Flat has been sinking by up to 2cm a year as a result of lithium mining, with an adverse impact on the local population of Andean flamingoes.

Marchegiani said policy in South America has broadly been pro-business, leading to a number of conflicts with local indigenous communities. These issues have led to court action and, in some cases, temporary injunctions on development. The risk of court action from communities and also a lack of water for the projects themselves are risks investors need to keep in mind, she added.

“The lack of strategic planning already caused damage [in northern Argentina] and it could cause a disaster with new operations coming in,” she said. “There’s a risk for investors. Even if you don’t care about the environment, you’re going to have the additional cost of bringing water from somewhere else. If that’s even possible.”

European policymakers can take heart in the fact that, despite high-profile examples of dissent, opposition to lithium mining is low in some parts of the continent. A 2025 study found that public support for a proposed mine in Finland was high, although a crucial factor for acceptance was employment prospects, illustrating the importance of involving local communities in the process.

Supporters of European industry point out that, given the environmental issues present in hard rock mining, there is an opportunity for the continent to pioneer a greener form of lithium extraction.

Many of the European projects rely on newer techniques like geothermal extraction techniques or “direct lithium extraction”. In geothermal lithium extraction naturally-heated underground brines are removed, with the potential of generating electricity from the heat. Direct lithium extraction refers to a suite of technologies that separate lithium from brine using chemicals or membrane technology. However, there are still question marks over its effectiveness and its “green” credentials.

Using DLE technology means the brine can be reinjected, leading proponents to argue it is better for the environment. However, some studies have shown that its use of freshwater can be significantly higher than traditional evaporation – up to 10 times in some cases. It also requires more energy, which can be generated from renewable sources, but could also lead to an overreliance on fossil fuels.

Experts also argue that DLE technology is not yet ready for full, commercial scale up. Federico Gay, an analyst at Benchmark Minerals, said a DLE plant can cost up to four times more to commission than a traditional one. Low lithium prices compound the cost issue.

The challenges in financing the European lithium expansion are illustrated by the story of Northvolt, the Swedish battery manufacturer, which was seen as Europe’s best hope of challenging Chinese dominance, according to the Guardian. It filed for bankruptcy in March after suspending construction of Europe’s first battery gigafactory, blaming “rising capital costs, geopolitical instability, subsequent supply chain disruptions, and shifts in market demand”.

Plans to create a similar battery plant in the US are also at risk of collapse after the Department of Energy rescinded a $197m federal grant for an Israeli company. It would be the first large-scale lithium battery plant in the country.

A circular economy

The logistical and financial challenges of getting this industry off the ground lead some to believe that Europe should focus instead on processing and recycling capacity.

“We do see that we will need some levels of mining under the right conditions, but also that we can meet a lot of demand through recycling,” Ritchey said. This could be accelerated by mandating specific levels of recycled mineral content within batteries at an EU level, she said.

Estimates vary for how much of European demand could be met by recycling old batteries and removing reusable lithium and other minerals, but a study from Transport and Environment suggested the practice could meet 14 per cent of lithium needs. The CRMA mandates that the EU should source 25 per cent of its lithium from recycling by 2030.

There are also many who argue that pursuing extractive industries like lithium mining in such strong fashion undermines the fight against climate change. The Lancet report states that, while battery recycling offers a partial solution, reducing car ownership and making smaller cars – with smaller batteries – could reduce lithium demand by 92 per cent by 2050. In Norway, which has the highest rates of EV ownership in Europe, smaller cars are incentivised.

“The use of water is a real issue. In Argentina, a community living close to a mine which opened in the 1990s claims that lithium extraction has caused the local river to dry up.”


DLE machinery at Neptune Energy, a company that wants to extract lithium from deep brine in Altmark

“While lithium is vital for the achievement of Europe’s green energy goals, even with high electric vehicle adoption, a 2°C rise in global temperatures remains likely,” the report reads. “Therefore, reducing overall vehicle use, not just gas-powered vehicles, is crucial.” Investment in public transport, including free-use schemes like those available in Luxembourg, is vital.

Leander Wolters, an academic who has researched the impact of EV supply chains on society, said policymakers should be looking at other options, including the promotion of cycling and ridesharing to reduce reliance on cars. The distribution of lithium is also important, she said. “Are we going to give it all to the big car companies? Maybe, if we are going to mine it, we should reserve a portion for electric buses or community energy grids,” she added.

There is a risk, some experts say, that unless the European lithium industry gets off the ground quickly, the ambitious goal to phase out combustion vehicles within a decade will be hard to meet. “I think there is a really big risk of a backlash and a changing of the policy goals,” said Månberger. “Will that [the 2035 goal] continue to be the goal going forward, or will it be postponed?” He said European governments, faced with a choice between importing from places like China and manufacturing at home, would have a difficult trade off. “You don’t become popular by outsourcing all of these manufacturing jobs,” he added.

Whichever direction Europe chooses to take, lithium will continue to be a vital element for the foreseeable future. Winning the race with China outright may be impossible, but by using levers like recycling and investment in better green policies, there could be a chance to narrow the gap.

“We’ll never be independent of lithium imports, either at the extraction or processing levels,” said Patrahau. “But there’s something to be said about having some kind of resilience, an alternative in case something happens with the relationship with China or with others that are also building up lithium processing facilities.” ■

EEI Analysis

India's solar gambit

Europe wants to diversify its supply chain, and India needs new markets for its solar manufacturing sector. Is the answer as simple as it sounds?

By **Xiaoying You,**
EEI writer and freelance journalist

India has recently announced a "historic milestone" for its solar industry: the country is now capable of making 100 gigawatts (GW) of solar panels each year domestically, thanks to a factory-building boom spurred by a multi-billion-dollar government campaign.

New Delhi's goal was clear: supporting home-grown companies and snatching some overseas markets in an industry dominated by China.

The South Asian country has risen to be the world's second largest solar panel maker after China, but the gap between the two is "huge", according to Yana Hryshko, head of global solar supply chain at research and consultancy firm Wood Mackenzie.

India accounts for around 5% of global manufacturing capacity, while China claims more than 80%, according to Wood Mackenzie's data. Southeast Asia – where many Chinese solar manufacturers have set up their overseas plants – makes up roughly 10%. The European Union – once the global forerunner of solar panel production – owns about 1% of the global pie today, the data shows.

Several major Indian solar manufacturers have pegged their growth partly on serving the lucrative US market, taking advantage of the import restrictions and high tariffs imposed by Washington on Chinese firms. Last year, roughly 30% of the solar panels produced in India were exported and 99% of them went to the US, according to a report by the Institute for Energy Economics and Financial Analysis (IEEFA) and JMK Research Analytics. By contrast, Europe's share in India's exports is so little that it was described as "abysmal".

Can Indian solar manufacturers benefit the EU, which gets nearly all of its solar panel imports from China? The answers vary depending on who you ask.

Some experts regard India as a good option, but others underline the harsh reality of the business world: European buyers want high-quality solar panels at the cheapest prices, and that means using Chinese vendors. The export prices of Indian solar panels are currently 1.5 to 2.5 times as much as Chinese ones, according to data supplied to *EEI* by different analysts.

Indian companies have an Achilles heel: at the moment, they are largely assembling parts imported from China into solar panels.

A photovoltaic factory near Jaipur

India's solar rise

For the past five years or so, India – the world's most populous country and the third-largest carbon emitter – has bet big on solar manufacturing.

The effort started in 2019 when the country announced that government projects must source solar panels from selected suppliers from what was known as the Approved List of Models and Manufacturers. The list officially took effect in early 2021, providing strong backing for domestic firms.

Also in 2021, the country introduced the so-called "production linked incentive" subsidy scheme, which handed out subsidies to companies planning to build factories along the solar supply chain. Almost simultaneously, India announced tariff hikes on solar panels and cells to discourage Chinese imports.

Between 2021 and 2023, India poured US$2.3 billion into the subsidies scheme, which triggered

Workers build transmission lines for a vast new PV project in Gujarat

Indian companies to plan 48GW of manufacturing capacity, according to Wood Mackenzie's data. Depending on the project type, manufacturers must finish building their facilities within three years or less, or face losing some of the funding.

"This is a very smart move," Hryshko says. "India wanted to be independent in the solar supply chain because the whole world was relying on China one way or another."

But Hryshko thinks that Indian companies have a long way to go if they want a chance to compete with their Chinese rivals.

"China is so far advanced in manufacturing, as well as module and cell technology," she says. "You can only compete with China if you create something extraordinary, if you create a new technology or if you deliver some technology that now only exists in theory and scale up its production."

For now, Indian solar manufacturers still rely on Chinese firms to supply the ingredients that go into their solar panels – a major drawback in its competitiveness.

According to Wood Mackenzie, China controls around 80% or more of the global manufacturing capacity in each of the four stages in the solar supply chain: polysilicon, wafer, cells and panels. Polysilicon is a purified form of silicon. It is melted at high temperatures to form blocks of silicon, known as ingots. They are then cut into thin slices known as wafers, which are used as bases for making solar cells. Dozens of cells are put together to make a panel.

India is now trying to encourage its solar manufacturers to move upstream. From June 2026, certain projects can only buy solar cells from government-approved vendors.

"For India to become a leader, it has to capture the entire value chain," Debmalya Sen, the president of India Energy Storage Alliance, tells *EEI*.

Looking overseas

India now has its own solar superstars. Some of the biggest names include Adani Solar, Waaree Energies, Vikram Solar and REC Group. Most of these firms make solar panels and cells, but only two companies across the nation – Adani Solar and Shirdi Sai Electricals – make wafers at present, according to Wood Mackenzie.

Wood Mackenzie's analysis shows that Adani Solar ranked 9th among the world's top 10 solar-panel manufacturers of 2024, after South Korea's Qcells and before China's TCL Solar and Tongwei, which tied at 10th.

Part of Adani's strength comes from the fact that it is part of Adani Group, which also owns one of the world's largest solar developers, Adani Green Energy, says Sarah Montgomery, chief executive of Infyos, a UK-based supply chain intelligence platform for renewable manufacturers. Although Adani Green Energy also sources products from other suppliers, it provides Adani Solar with a strong go-to market, she says. Many Chinese solar companies have similar setups, which enabled them to grow in their early stages.

India's rapid renewable expansion has created a strong home market for domestic players, yet many of them have

"For now, Indian solar manufacturers still rely on Chinese firms to supply the ingredients that go into their solar panels"

linked their growth strategies to exporting panels to high-profit overseas markets.

Between fiscal years 2022 and 2024, the value of Indian solar exports surged by more than 23 times, primarily to the US where exporting is hard for Chinese companies, according to the IEEFA and JMK's report. The US has blocked imports from some Chinese solar panel makers due to forced labour concerns and put hefty tariffs on others. Anti-dumping levies are also in place on some Chinese-owned factories in four Southeast Asian countries.

In fiscal year 2024, three companies – Waaree Energies, Adani Solar and Vikram Solar – accounted for most of India's solar exports, the report said. Each of them shipped more than half of its annual actual production abroad, it wrote.

The US export rush happened when "many pieces were coming together", according to Charith Konda, an energy specialist at IEEFA. They included many American companies' adoption of a "China plus one" strategy and the good trade relations between India and the US, Konda tells *EEI*.

But the strategy is facing uncertainty after the Trump administration slapped 50% tariffs on goods from the South Asian country, which included a 25% penalty for trading with Russia. US solar manufacturers have also filed petitions urging Washington to impose anti-dumping duties on solar cells and panels from India.

"India urgently needs to diversify into alternative international markets to sustain the competitiveness and continued growth of its solar manufacturing sector," says Rajan Kalsotra, an India-based senior consultant at EUPD Research, a German market intelligence firm.

Another crucial factor is that India's solar manufacturing industry is heading towards overcapacity. By 2030, the country is expected to be able to produce 38GW of wafers, 115GW of solar cells and 190GW of solar panels annually, but the domestic demand for solar power installations is projected to be just 30-35GW in that year, according to EUPD Research's data. This imbalance highlights the need for Indian solar manufacturers to seek large export destinations, with Europe "likely being a key market", Kalsotra tells *EEI*.

Although there is "no one straight answer" as to why Indian solar companies went after the US instead of the EU, the fact that the EU has more complex regulations and stringent technical standards probably played a role, according to Konda.

Montgomery agrees that Indian solar companies must find more overseas markets. But she warns that the move will require them to understand the local context of different regions, such as their sustainability requirements and energy market regulations, and that is "an area the Chinese manufacturers are very strong in".

EU's dilemma

The EU gets around 98% of its solar panel imports from China, a clearly uncomfortable fact for many.

"Our dependency on Russian gas has taught us a number of lessons. Let's not replace that dependency with a reliance on others to produce solar panels and other technologies we rely on," Thierry Breton, the EU's then Commissioner for Internal Market, said in 2023 when the bloc proposed a Net-Zero Industry Act to drive domestic clean-tech industries. The act, formally adopted in June 2024, has set a target for the EU's net-zero industries to have enough annual manufacturing capacity to meet "at least 40%" of its yearly deployment needs by 2030.

Brussels has also announced a specific goal for its solar industry: at least 30GW of annual manufacturing capacity across the supply chain by 2030. At the moment, the figure is just shy of 10GW for the EU, with 6.7GW for solar panels and 2.9GW for solar cells, according to EUPD Research.

The clock is ticking for all countries to roll out green energy so as to combat climate change, but the EU has found itself facing a dilemma between fast-tracking solar power deployment and cutting back its dependence on Chinese panels.

Among researchers, analysts, industry participants and politicians, there seem to be widely different views on the difficult situation, with debates largely focusing on two questions: whether the EU should block cheap Chinese panels and turn to more expensive alternatives; and whether the bloc should reboot its own solar manufacturing – and if so, at what cost.

This is not a new headache. The EU has been trying to save its solar industry from Chinese competitors for more than a decade. One of its biggest moves yet was slapping a 47% anti-dumping tariff on Chinese solar manufacturers between 2013 and 2018. There was an exception, though: Chinese companies were allowed to enjoy a 0% levy if they exported their panels in to the EU at higher prices – €0.56 per watt or above – and followed a collective annual quota that represented roughly 60% of the EU's yearly demand at that time, according to Big Solar Nation, a book that explains the rise of China's solar industry.

"[That tariff] didn't work. European manufacturing didn't come," says Ben McWilliams, an affiliate fellow at Bruegel, a Brussels-based economic think tank.

Unlike the US, which has used tough policies to shut out Chinese solar imports, there are less hard restrictions in Europe to really drive diversification, according to Montgomery. Therefore, there are no real consequences for "financially driven" European renewable energy developers continuing to depend on Chinese suppliers, she notes.

McWilliams cautions against any new measures aimed at barring Chinese products, largely because it could make solar panels more expensive in Europe. Currently, there is no tariff on Chinese solar panels or cells that come into the EU.

"The access to cheap solar panels is just so important for the energy transition, which is not just about climate, but also energy security and competitiveness," McWilliams tells *EEI*. It may be beneficial for the EU to look into lowering the portion of Chinese imports down to 90 or 80%, but "on the whole, it is a good policy [for the EU] to continue importing as many solar panels as it can install from China," he says.

Some researchers disagree. "Europe must diversify rather than putting all its eggs in the China basket when it comes to solar," Remco de Boer, an Amsterdam-based independent energy researcher, tells *EEI*. "If India has good solar panels that meet EU standards, even if they are a bit more expensive, we have to give them a chance."

De Boer considers it crucial that European governments take immediate actions to encourage companies to buy from alternative sources. He stresses that price cannot be the only criterion: "The sooner politicians acknowledge this, the better."

Following its invasion into Ukraine, Russia – once the EU's major energy supplier – drastically cut its gas export to the bloc in 2022 to pressure Brussels to pull back its support for Kiev. But Cecilia Trasi, a senior policy advisor at ECCO, an Italian climate change think tank, warns against directly comparing Russian gas with Chinese solar panels in their importance to the EU's energy security.

"Even if all the panel imports were to stop coming into Europe suddenly, the solar panels that are already installed [in the EU] would keep on producing electricity," Trasi tells *EEI*. "Disruption to solar panel imports would not have any direct impact on the current energy security. It would mostly slow down our ability to meet the targets for the deployment of renewable energy."

However, Trasi agrees that relying on a single country for solar panels – or any products – makes the EU vulnerable. But there are ways to mitigate those vulnerabilities in the short term, such as by sourcing from third countries and stockpiling panels to create a buffer.

Close the gap

Multiple sources in Europe agree that Indian solar companies can be good alternatives for the EU – but only if they can outcompete their Chinese competitors on price and quality.

Kalsotra is positive about Indian companies narrowing their cost gap once they start producing raw materials at scale. His analysis shows that the price of Indian solar panels could potentially drop to roughly 1.2 times that of comparable Chinese products, from the current 1.6 times. Rising European demand and a potential free-trade agreement between Brussels and New Delhi – which the two sides are negotiating – could strengthen India's position over China, he says.

The key will be Indian companies proving themselves through large-scale projects outside India, Montgomery says. "[European] developers are cautious, so they want technology that is tested, certified, and meets Europe's tougher quality and safety standards," she explains.

Joseph Dellatte, head of energy and climate studies at Institut Montaigne, a Paris-based think tank, says he has noted interest from some European decision makers in India's solar supply chain. He thinks India is one of the few countries that have the potential to help the EU diversify its solar supply chain, apart from rebooting home manufacturing. "At least, it means you do have other players on the market," Dellatte tells *EEI*.

But he emphasises that Indian companies must move from assembling made-in-China parts to also producing raw materials themselves in order to win European orders.

Others think there are reasons and hopes for the EU to reshore its solar industry. According to a study by SolarPower Europe, a trade association, and Fraunhofer Institute for Solar Energy Systems in Germany, Brussels' 2030 solar-manufacturing target is "both technically and economically achievable", but only if the EU and member states act swiftly to provide the right support. An EU-level financial scheme is needed for scaling up production, while member states must take an "EU-preference approach" to create a market for made-in-EU solar products, the study said. It also projected each GW of EU-based annual solar manufacturing capacity to generate up to 2,700 new jobs and €66.4 million per year in tax and social revenues.

Some countries have started to take actions. Italy recently became the first EU country to require solar developers to source "non-Chinese" components in order to win contracts under a government renewable programme. But there are voices that are firmly against trade protectionism, pointing to the importance of a free market in propelling innovation.

On the other end of the spectrum, a policy brief published by Bruegel argued that the EU "does not need domestic solar PV manufacturing to accelerate its decarbonisation" because the global solar PV market is so oversupplied.

"At the moment, for Europe to produce solar panels, it would require huge subsidies," says McWilliams, a co-author of the brief. For the EU, a better strategy would to direct its resources onto other clean technologies, such as green steel and electric vehicles, where EU companies can still grow their market shares, according to him.

Trasi, also a co-author of the Bruegel report, highlights that if the EU were to support a home-grown solar industry, subsidies should only be given for spurring innovation, not chasing cost parity with the Chinese.

The "most optimal" policy, from her perspective, is to allow Chinese imports to keep coming without barriers while focusing on supporting solar technologies that do not need the Chinese supply chain. She cites cadmium telluride as an example of alternative technologies "for which Europe does have a competitive advantage". This type of solar panel does not use polysilicon, so it can potentially help manufacturers move away from Chinese suppliers. (China-based industry experts say that some Chinese companies have pursued that technology, but it failed to survive market competition because the chemicals used are toxic and the resulting panels are less efficient than polysilicon ones.)

For people working in supply chains, everything still comes down to cost and profit, particularly in a world of global trade and increasing solar revenue "cannibalisation" – a phenomenon that sees solar power prices collapse at the same time the most solar power is generated, effectively eroding the developers' income. This forces them to be "very pragmatic," Montogomery says.

"The majority of renewable developers will only purchase EU solar panels if they hit cost parity with Chinese panels," she concludes. ■

Who will lead the nuclear renaissance?

binding .energy

Who will lead the nuclear renaissance?

Across the global energy landscape, nuclear technology is undergoing a renaissance, driven not by nostalgia, but by innovation, urgency, and capital. Once viewed as a legacy industry, nuclear has re-emerged as one of the most dynamic frontiers of energy innovation. The race is on: between fusion and advanced fission systems, between start-ups and incumbents, and between regions striving for technological sovereignty and energy resilience.

Private capital bets big on nuclear

Over the past five years, private investment in nuclear innovation has surged to unprecedented levels. According to the Clean Energy Platform, private funding for fusion companies alone has reached around 11 billion USD by 2025, with Commonwealth Fusion Systems and Helion Energy leading the field, together attracting almost 5 billion USD. This influx signals that investors now see nuclear not as speculative science, but as deep tech on the verge of industrialisation.

Advanced fission is following a similar trajectory. A new generation of compact, modular, and inherently safe systems is reshaping the sector's economics and supply chains. Unlike the gigawatt- scale reactors of the past, today's concepts are designed for distributed deployment, hybrid energy systems, and industrial heat applications.

Innovation as a geopolitical contest

The global race to commercialise new nuclear systems is no longer confined to the lab. It is unfolding as a geopolitical competition in which mastery of the nuclear value chain equates to strategic advantage. The United States, Europe, and East Asia are investing heavily in both fission and fusion to secure future energy independence, decarbonisation, and industrial competitiveness.

Europe finds itself both competitor and collaborator. France and Finland are expanding their nuclear ambitions; the United Kingdom pursues a dual strategy of fusion and small modular reactors; and Eastern Europe is positioning itself as a proving ground for international cooperation. In Romania, for example, RoPower is advancing plans for an SMR project with strong local and international backing.

From research to demonstration

For both fusion and fission, the defining challenge of the decade is the same: who will deliver first-of- a-kind demonstrators at commercial scale?

In fusion, companies such as Focused Energy in Europe, alongside Helion Energy and Commonwealth Fusion Systems in the US, are racing to achieve net-energy operation within the next ten years. Progress in laser- and projectile-based fusion concepts is accelerating, turning once-theoretical models into engineering realities.

In fission, innovation is diversifying rapidly. In the US, Nano Nuclear Energy is developing micro- modular reactors that can be manufactured and deployed rapidly for both civil and defence applications. In Finland, Steady Energy is designing district-scale SMRs optimised for heat supply in cold-climate urban networks. Each of these projects reflects a broader trend: nuclear energy is becoming smaller, faster, and more flexible, tailored for the decentralised, electrified economies of the 2030s.

Germany's fusion leap: repurposing Biblis

Germany is also seeing a quiet but significant shift in how it approaches the future of nuclear innovation. The former Biblis nuclear power plant site is being reimagined as a Fusion Innovation Hub, a pioneering redevelopment led by the former operator RWE in cooperation with partners including Focused Energy. The initiative aims to establish demonstration facilities and a technology campus for the world's first laser-driven fusion power plant prototype.

Biblis symbolises a broader transformation: how legacy infrastructure can become the foundation for a new generation of clean-energy technologies. Yet turning such a vision into reality requires coordinated commitment, from policymakers, industry, investors, and research institutions.

Building the ecosystem behind the breakthrough

The race for reactor deployment is not just about hardware. Success will depend on ecosystems, supply chains, licensing regimes, and investment frameworks that can scale new technologies safely and reliably. From high-temperature materials and precision components to cryogenic systems and tritium handling, many parts of the industrial infrastructure still need to be built.

Europe's role in shaping the nuclear future

Europe's strength lies in its research excellence and regulatory credibility. Programmes such as EUROfusion, the OECD NEA, and national innovation agencies have created a scientific foundation that few regions can match. The next step is translating this knowledge into competitive industrial capacity and doing so quickly enough to remain globally relevant.

That is the mission of "binding. energy", taking place 3–5 February 2026 at Eurogress Aachen, Germany. The conference serves as a high-level meeting point for leaders from industry, policy, research, and investment. It addresses not only fusion and fission as distinct technologies, but also their convergence, how hybrid innovation, supply-chain cooperation, and regulatory alignment can accelerate deployment.

Speakers and participants include pioneers from fusion and advanced fission start-ups, institutional investors, and representatives of licensing authorities. The event's defining quality is its peer-level dialogue: experts discuss challenges and solutions openly, from component qualification to financing and workforce development. ■

For more information visit www.binding.energy

Scan for partner event website

Save the date: EUSEW, 9–11 June

SUSTAINABLE ENERGY WEEK

EU Sustainable Energy Week 2026 to focus on a clean, secure and competitive Energy Union Brussels

The 20th edition of European Sustainable Energy Week (EUSEW) will take place on 9-11 June 2026, under the overarching theme of 'A clean, secure and competitive Energy Union', the European Commission has announced.

Meeting in Brussels and online, EUSEW – Europe's largest annual gathering focusing on renewables and efficient energy use – will focus on the importance of building a secure and resilient Energy Union and providing clean and affordable energy. The EUSEW Policy Conference features over 60 dynamic and innovative sessions hosted by the clean energy community.

Next to the policy sessions, the event offers keynotes, EUSEW Awards ceremony, as well as networking opportunities at the Energy Fair celebrating the people, projects, and initiatives advancing Europe's transition to clean and sustainable energy. Building up to the Conference, the Commission has now opened a call for policy session proposals until 22 January 2026, inviting industry representatives, policy experts, members of civil society and academia to shape the event and contribute with their insights and expertise to the discussions on clean energy.

EUSEW 2026 will also award outstanding individuals and projects for their innovation and efforts in the field of energy efficiency and renewables in three categories: Local Energy Action, Women in Energy, and, for the first time this year, SMES driving Energy Efficiency. Applications for the EUSEW Awards are open until 29 January 2026.

A timeline, Q&A and the Info Session recording will be available on the EUSEW 2026 info page. Other opportunities to be part of the EU Sustainable Energy Week such as becoming an exhibitor at the Energy Fair, a Young Energy Ambassador or to organise a local Sustainable Energy Day will become available during January and February 2026.

European Sustainable Energy Week is the biggest annual event dedicated to renewables and efficient energy use in Europe and is organised by the European Commission's Directorate-General for Energy and the European Climate, Infrastructure and Environment Executive Agency (CINEA).

The 20th edition of EUSEW will take place in a hybrid format, onsite in Brussels and online, from 9-11 June 2026. European Sustainable Energy Week consists of a three-day Policy Conference, the European Sustainable Energy Awards Ceremony, the Energy Fair and the sixth edition of the European Youth Energy Day. Participants will also have access to independently organised Sustainable Energy Days, taking place in online and physical formats worldwide. ■

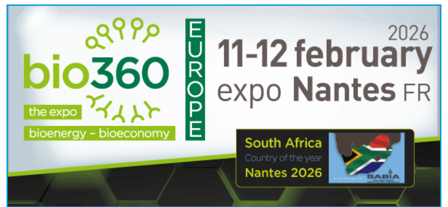
For updates on the agenda and location of the events, please refer to ec.europa.eu/eusew and #EUSEW2026 on social media.

Events

Upcoming events 2025/2026

JANUARY
9–18
Brussels Motor Show
Brussels

FEBRUARY
9–10
Decarbon Congress
Vösendorf



FEBRUARY
11–12
Bio360
Nantes

FEBRUARY
24–27
World Sustainable Energy Days (WSED)
Wels

ICM Forum (previously CCUS Forum)	8-9 Dec	Athens
Biogas Convention and Trade fair	9-11 Dec	Nuremburg
2026		
Brussels Motor Show	9-18 Jan	Brussels
GPPS Energy Forum	14-15 Jan	Zurich
EERA DeepWind	14-16 Jan	Trondheim
Fuels of the Future	19-20 Jan	Berlin
WFO Global Summit	20-21 Jan	Barcelona
Central European Biomass Conference (CEBC)	21-23 Jan	Graz
Horizon Europe Info Days, Cluster 6	22-23 Jan	Brussels
European Carbon Capture, Utilization and Storage	26-27 Jan	Amsterdam
Hyvolution	27-29 Jan	Paris
Handelsblatt Energie Gipfel	27-29 Jan	Berlin
Sarajevo Energy Forum	28-30 Jan	Sarajevo
Elmia Solar	3-5 Feb	Jönköping/
Binding.energy	3-5 Feb	Aachen
Energy Week Black Sea	4-5 Feb	Romania
Decarbon Congress	9-10 Feb	Vösendorf
RTR Conference (Road Transport Research)	10-12 Feb	Brussels
E-World Essen	10-12 Feb	Essen
International Energy Week	10-12 Feb	London
E.DSO FutureGrid Innovation summit	11 Feb	Brussels
Bio360	11-12 Feb	Nantes
ESF Europe	24-26 Feb	Antwerp
World Sustainable Energy Days (WSED)	24-27 Feb	Wels
RICH Second Symposium for Research Infrastructures	25-26 Feb	Rome
Energy Supply Chain summit	25-26 Feb	Berlin
GeoTHERM Expo and Congress	26-27 Feb	Offenburg
Balkan Solar Summit	26-27 Feb	Banja Luka
Key Energy Transition Expo	4-6 Mar	Rimini
Clean Energy Transition Conference	5 Mar	Brussels
EVision	5-6 Mar	Brussels
LNG Congress	9-11 Mar	Barcelona
Open Energies the Intelligent Energy Event	10-11 Mar	Lyon
Hydropower R&D Days	11-12 Mar	Kalstad
Carbon Capture Europe Summit	11-12 Mar	Rotterdam
The Distributed Energy Show	11-12 Mar	Birmingham
The Energy Storage Show	11-12 Mar	Birmingham
European Hydrogen Energy Conference (EHEC)	11-13 Mar	Seville
Vaasa EnergyWeek	16-19 Mar	Vaasa
Baltic Nuclear Energy Forum	16-20 Mar	Gdańsk
H2 Cluster	17-18 Mar	Belgrade
Green Marine Transport	18-19 Mar	Amsterdam
Safe, Sustainable, and Swift Reconstruction of Ukraine	19-20 Mar	Lviv
The Future	23 Mar	Antwerp
SEED Sustainable Energy Education conference	24-25 Mar	Utrecht
Datacloud Energy Europe	25-26 Mar	Brussels
EnergyON Summit	25-26 Mar	Poznań
ISEC	14-16 Apr	Graz
H2FC Hydrogen + Fuel Cells Europe	20-24 Apr	Hanover
Wind Europe 2026	21-22 Apr	Madrid
Belgrade Energy Forum	28-29 Apr	Belgrade
Coastlink 2026	6-7 May	Humber
Energy Mediterranean Exhibition and Conference	12-14 May	Bologna
All-Energy Exhibition and Conference	13-14 May	Glasgow
SEANERGY	19-20 May	Nantes
EUBCE European Biogas Conference and Exhibition	19-22 May	Amsterdam
CO2 Capture, Storage and Reuse 2026	20-21 May	Copenhagen
TORQUE	3-5 Jun	Bruges
Eurelectric Power Summit	3-4 June	Helsinki
Festival of the New European Bauhaus	9-13 Jun	Brussels
European Sustainable Energy Week (EUSEW)	9-11 Jun	Brussels
Intersolar Europe 2026	23-25 Jun	Munich
Eurosun Conference	14-18 Sep	Freiburg
Renewable Energy Conference (GRCREN 2026)	17-18 Sep	Rome
Wind Energy Hamburg	22-25 Sep	Hamburg

EUBCE
34th European Biomass Conference & Exhibition

MAY
19–22
EUBCE
Amsterdam

SUSTAINABLE ENERGY WEEK

JUNE
9–11
European Sustainable Energy Week (EUSEW)
Brussels

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