EUROPE

40th overseas excursion of Lämpövoimakerho 2024

LVK GERMANY | BELGIUM | SWITZERLAND | FRANCE


Wind Multiplikator

Lämpövoimakerho's Overseas Excursion 2024

Destinations

Hamburg 18.-19.8.
Emden & Aurich 19.-21.8.
Dortmund 21.-22.8.
Brussels 22.-24.8.
Zürich 24.-26.8.
Geneva 26.-27.8.
Martigny 27.8.-28.8.
Amberieu-en-Bugey 28.-29.8.
Marseille 29.-30.8.
Nice 30.8.-1.9.

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Excursion Publication

Circulation
300
Layout and Editing
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Printing House
Kirjapaino Bookcover Oy
Publishing Date
January 2025
Online Version
lampovoimakerho.fi

Excursions in Germany
Wind Multiplikator
Enercon Factory
Storag Etzel
Datteln 4 Coal-fired Power Plant

Excursions in Brussels
ENTSO-E
Wind Europe

Excursions in Switzerland
Eglisau Hydropower Plant
CERN
Nant de Drance Pumped Hydro Plant

Excursions in France
Bugey Nuclear Power Plant
ITER

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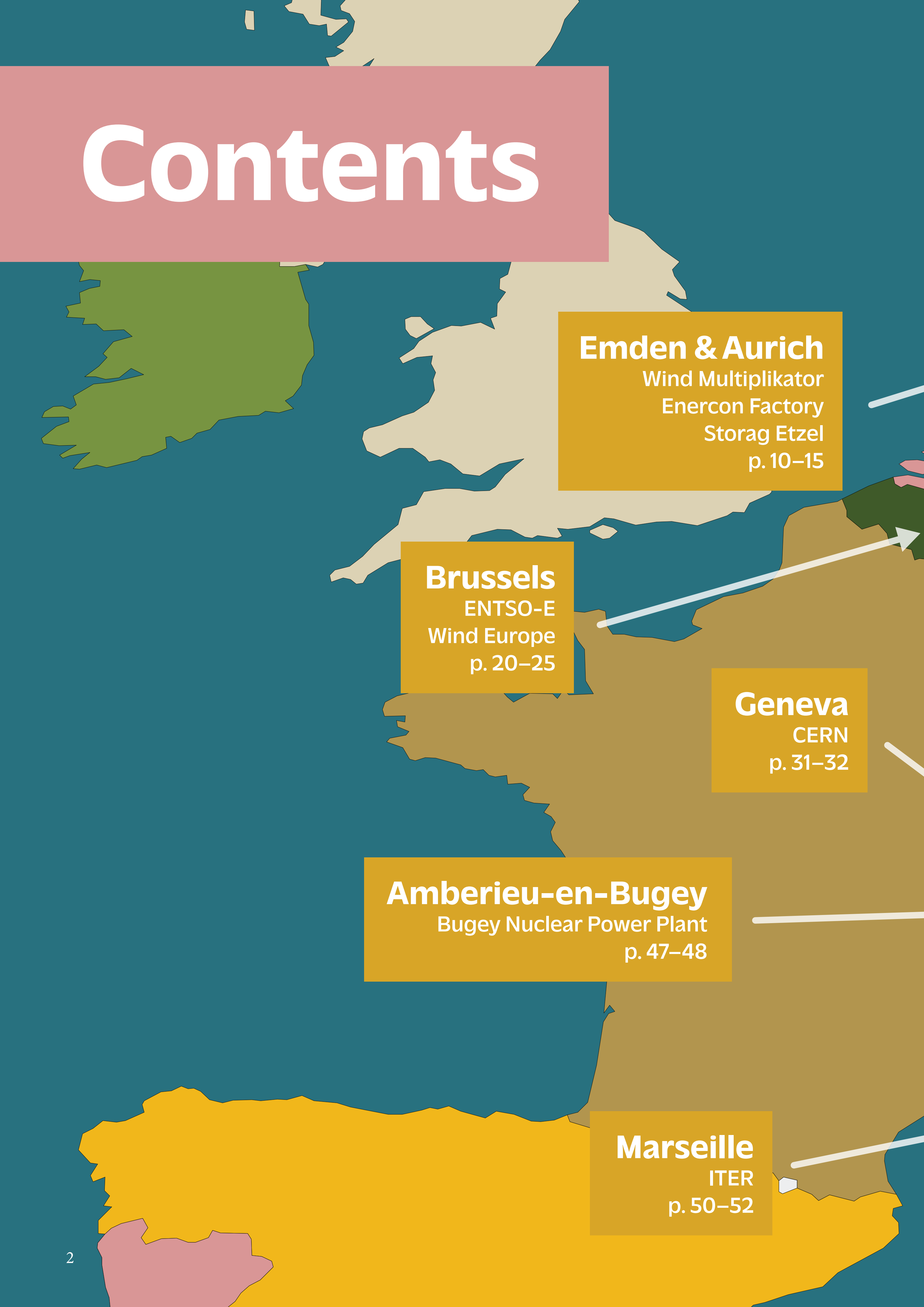

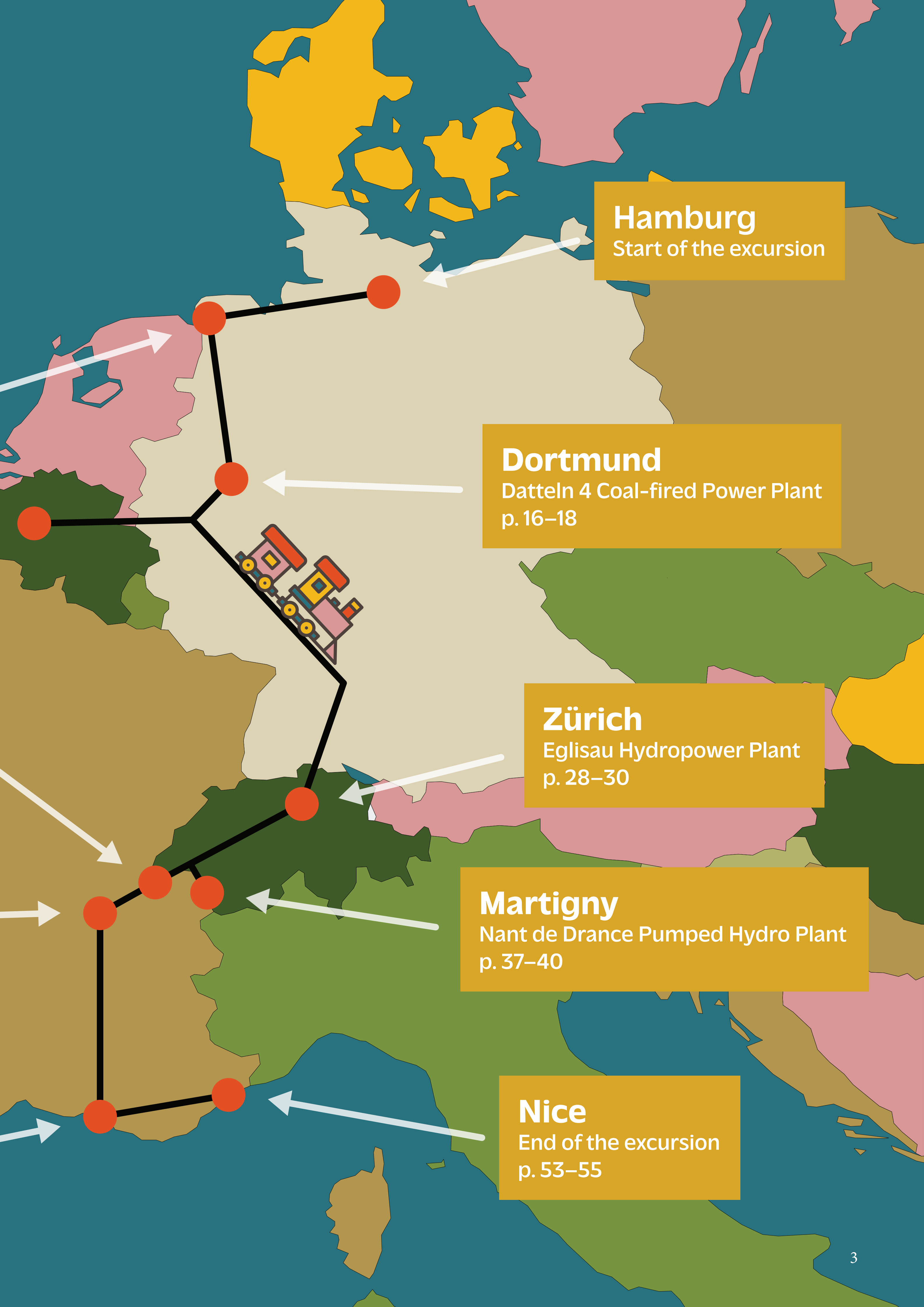
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Excursion Leader's Preface

The 40th abroad excursion of Lämpövoimakerho marked a great milestone in the long history of our beloved engineering club. Coincidentally, we decided to head back to the club's roots. Lämpövoimakerho was founded in 1966 for an abroad excursion to West Germany. While the two Germanies have since united, we honored the history of Lämpövoimakerho by starting our two-week journey in Western Europe from the German city of Hamburg.

Fifteen days, eleven excursions, ten cities, four countries and nine days of traveling by train across Western Europe with sixteen participants required quite a bit of planning. However, with an excellent organizing team, anything is possible! Planning began already in the spring of 2023 as we explored potential destinations for the excursion. We ultimately chose Western Europe due to the region's many fascinating energy projects. Moreover, as a forerunner in climate change mitigation, Europe offered an exciting backdrop for our journey. We also opted to travel by public transport as it was relatively cheap, climate friendly, and convenient. Well, the convenience aspect was debatable, but aside from Deutsche Bahn, everything went surprisingly smoothly.

We had a plethora of unique and fascinating excursions from German coal-fired power plants to Swiss hydropower and French Nuclear power plants, representing the diversity and complexity of the continental European energy system. We were introduced to the manufacturing and maintenance of wind turbines and caught a glimpse of the future energy system during our visits to ENTSO-E and ITER. The insightful discussions with our hosts shed light on challenges in national and EU-level energy policies. It was also inspiring to meet Finnish experts working across Europe, some even working on groundbreaking projects like the ITER.

Despite our ambitious schedule, we made time to admire the beautiful architecture of European cities and the breathtaking views in the Alps. And of course, we arranged time for leisure activities as well, with highlights including wine tasting at the picturesque Domaine du Daley vineyard and snorkeling in the Mediterranean Sea.

I want to thank all our sponsors for enabling our unforgettable excursion and for helping us continue the tradition of Lämpövoimakerho's abroad excursions! I also wish to thank our excursion hosts for the excellent excursions and insightful discussions.

I wish you pleasant moments while reading about our experiences during the trip!

Onni Tikkanen

This picture was taken on the lower dam of the Nant de Drance pumped hydro storage plant, situated at 2,200 m above sea level in the Alps near the Swiss-French border. Picture: Lauri Heroja

Professor's Greetings

First of all, kudos to the trip organisers. Planning and executing an enjoyable trip across multiple weeks and countries for fifteen students (and one alumnus) is no easy feat. Moreover, financing the trip under the economic conditions of the past years has required determinism and optimism, especially as many decision-makers have a view (an outdated one, I learned) that trips like this perhaps have less to do with learning and growing than simply having a blast. Don't get me wrong, we had a blast, but the emphasis given to visiting intriguing sites and institutions was respectable. Moreover, the atmosphere among the students was that of curiosity, rapport, and humour, despite all the early mornings, sketchy hotel dorms, massively delayed trains, and other hardships that are a part of proper adventures.

In addition to learning and experiencing, the excursion was an adventure seasoned with nostalgy for me, as I was attending and organising two similar trips during my own studies. It warmed my heart to see that LVK and its members are still thriving, and I'm relieved to see that the massive challenges the energy sector is facing in the coming decades is drawing some of the brightest minds to solve them.

I'm sincerely grateful to all the companies and individuals who supported this excursion and thus made it possible. It is an investment that pays itself back through the broadened perspective of the young talents. Moreover, I'm grateful and honoured for the possibility to share the experience with the students. Thank you, LVK!

Jaakko Jääskeläinen

Jaakko enjoying the mountain views in Switzerland and standing in front of the European Commission Building.

Germany: Balancing Renewable Ambitions and Fossil Realities

Country Overview

Picture: Etienne Girardet on Unsplash

Germany, home to over 83 million people, is also a major European power market where consumption and production levels are higher than in the whole Nordics. Thus, everything that happens in Germany regarding energy and electricity affects the whole Europe. The Short-Run Marginal Cost (SRMC) of natural gas sets the upper limit for electricity prices [1]. After the Russian invasion of Ukraine, the gas prices peaked strongly, raising the SRMC and leading to very high electricity prices in Germany and consequently Europe.

Germany already has a significant share of wind and solar power, and for the first time in 2023, renewable energy sources covered more than 50% of its electricity generation [2]. However, we all know how unreliable these sources can be due to strong weather dependency. As a result, the residual load that needs to be covered by thermal power can sometimes be very high. In addition, the share of primary energy consumption from fossil fuels was 75% in 2023 [3], reflecting Germany's reliance on non-renewable sources.

We started our journey in Hamburg, and proceeded to Emden where we had the pleasure of visiting Wind Multiplikator and Enercon, but also Datteln 4 in Dortmund. The excursions in Germany were chosen specifically that we could explore the energy field of Germany diversily from the wind-oriented North to the industry-oriented Ruhr region.

Our excursion group wondered how Germany could achieve its 2050 greenhouse gas neutrality target, when there's still so strong reliance on gas, coal, and lignite, and no nuclear power. Our host at Datteln 4 told us that he, too, was quite stunned by some decisions made by German politicians, particularly the decision to phase out nuclear power after the Fukushima nuclear accident in 2011. He joked that when it comes to politics, you just have to sit back and see what happens – there's really not much a power plant worker can do to influence Germany's energy policy decisions.

To a nuclear-loving Finn, it still seems odd that Germans are so strongly against nuclear power, especially when it has been studied how much safer nuclear power is compared to fossil fuels in terms of air pollution, accidents and greenhouse gas emissions [4]. However, it wouldn't be unprecedented for a country to change their view of nuclear power – I could name drop Sweden, for instance – so fingers crossed that Germany would realize nuclear power's contribution to the green transition. Maybe, once small modular reactors are commercialized, Germany could use them to produce heat, as they operate at lower pressures and pose smaller risks than reactors used for electricity generation.

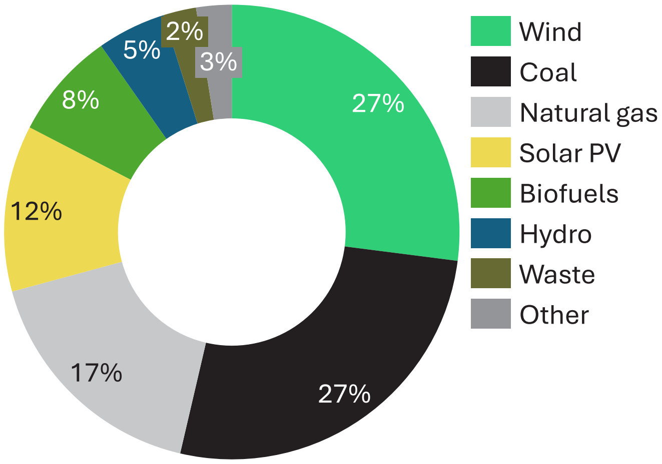
In Germany, we also learned about

the country's industries. The Ruhr region in western Germany is one of Europe's largest industrial centers. The region's economy developed around coal mining, coal-fired power generation, and heavy industries that rely on coal, such as the steel industry. The peak of the industry was seen in 1955, but after that, hard coal production decreased rapidly due to international competition. Nowadays, the Ruhr region has transitioned to a more diversified economy, focusing on services, technology, and renewable energy. [5]

Germany is set to phase out coal by 2038. There is no specific plan to phase out natural gas yet, but due to recent high volatility of gas prices, I believe that ordinary German people would be eager to switch from natural gas, if only the change were easy to make. One solution that has been discussed to replace natural gas is hydrogen. With a large-scale hydrogen economy, Germany could leverage its existing industrial infrastructure and expertise to produce and distribute clean energy. However, challenges related to efficiency, storage, and the production costs of green hydrogen still need to be addressed, as well as all the clean electricity needed for green hydrogen production. Nevertheless, with increasing global interest in hydrogen as a key element of the energy transition, Germany has the potential to lead in this area, especially given its ambitious climate targets.

Inka Arposalo

Germany electricity generation by source, 2023



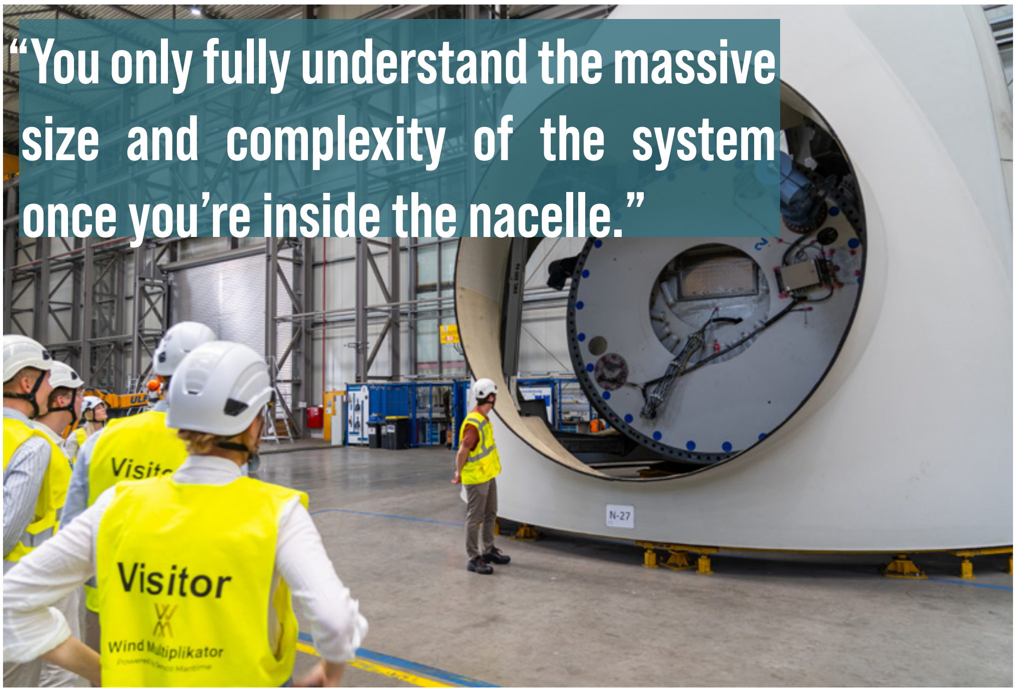
[1] Zakeri, B., Staffell, I. et al. The role of natural gas in setting electricity prices in Europe. Energy Reports, 2023. Vol. 10. P. 2778-2792. Viewed on 13.11.2024. Available: doi 10.1016/j.egyr.2023.09.069.
[2] The Energy Supply 2023 – Annual Report of the BDEW – UPDATE. BDEW, 4.6.2024. Viewed on 24.8.2024. Available: https://www.bdew.de/service/publikationen/jahresbericht-energieversorgung/
[3] Ritchie, H., Roser, M. Germany: Energy Country Profile. Our World in Data, 2024. Viewed on 13.11.2024. Available: https://ourworldindata.org/energy/country/germany
[4] Ritchie, H. What are the safest and cleanest sources of energy? Our World in Data, 2020. Viewed on 13.11.2024. Available: https://ourworldindata.org/safest-sources-of-energy
[5] Germany: The Ruhr Region's Pivot from Coal Mining to a Hub of Green Industry and Expertise. World Resources Institute, 1.4.2021. Viewed on 24.9.2024. Available: https://www.wri.org/update/germany-ruhr-regions-pivot-coal-mining-hub-green-industry-and-expertise#:~:text=In%20the%201950s,%20the%20Ruhr%20region

The excursion group just arrived in Hamburg to kick off the trip – we had a great time exploring the city!

When Windy Meets Wavy

Wind Multiplikator

LVK's 40th abroad excursion started with an excursion to Wind Multiplikator in Emden, Germany. With the rapid growth of onshore and offshore wind power, there is an increasing demand for maintenance work. Offshore wind, while requiring no more maintenance than onshore, has bigger challenges due to the harsh sea conditions. Specialists to work in these conditions are hard to find, and Wind Multiplikator is one of the few companies who currently service offshore wind parks.



> "You only fully understand the massive size and complexity of the system once you're inside the nacelle."

The excursion offered an interesting deep dive into the mechanics and unique challenges of offshore wind maintenance. The first thing that struck us was the scale of every component involved in an offshore wind farm. For example, the bearing that allows the hub to rotate and twist the axle to generate electricity measured around 4 meters in diameter and 1 meter tall. We also saw damaged hubs undergoing repair, which couldn't be fixed on site. To solve this, the company creates replicas of the hubs and transports them to the site using helicopters. Every part they send to the offshore site undergoes rigorous testing on their own test benches to ensure functionality and reliability. These benches also serve as training grounds for workers, allowing them to practise maintenance work in a controlled and safe environment. In cases where the entire nacelle of a wind turbine needs replacement, they must place a weight atop the tower to maintain similar pressure. Without this, the tower would be vulnerable to damage from strong winds or waves.

Every offshore wind farm requires annual maintenance, which involves a lot of inspections. The main focus is on checking the electrical systems inside the nacelle and tightening any loose bolts, often loosened by the turbine's vibrations. Approximately every eight years, more extensive maintenance is carried out, including servicing the oil filters and cooling systems. Many variables are monitored automatically, such as detecting particles in the oil to determine when the filter needs replacing. Additionally, bolts are equipped with sensors that can detect if they are loose or damaged, making repairs easier. The greasing system for the massive bearings is also automated, injecting fresh grease daily while removing the old grease to ensure smooth operation.

The highlight of the excursion was our visit to the nacelle of the Bard 5.0 offshore wind turbine. You only fully understand the massive size and complexity of the system once you're inside the nacelle. Every component seemed designed for its specific purpose, and our guide's knowledge of the nacelle was impressive. The most amusing part was the foldable dining table for workers' breaks, and the emergency exit rope—imagining a descent from 90 meters in the middle of the sea was quite something! The nacelle had two floors packed with electrical cables and cabinets, all managing the electricity generated. The turbine's generator featured a transmission system that ensured a steady 50 Hz output, but this system required more maintenance compared to modern power converters. Naturally, all the electrical cabinets were remotely controlled for easier management.

After the tour inside, we stepped outside to see the massive wind turbine blades, which couldn't be housed indoors due to their size. The focus here is on repairing and maintaining the blades. One key part of maintenance involves applying a special fabric that protects the blades from salt and other impurities in the air, as the blade tips can reach speeds of up to 300 km/h. This protective fabric needs to be replaced around every four years for offshore blades. During this maintenance, they also replace the 100 bolts that secure each blade to the hub and repair any fiberglass damage. It's important to ensure the ends of the blades remain perfectly round, as changes in air temperature and moisture can cause warping. To maintain this shape, they use a specialized mould during repairs.

The final stop of our excursion was the control room, where nearly 1 GW of wind power is managed and monitored. Staffed 24/7, the control room makes sure that the various wind farms operate at maximum capacity safely. A common issue they face is fishing vessels, which come to the wind farm areas because of the abundant fish. As a result, they often must direct these ships away from the turbines. The size of these farms is impressive—the Bard 5.0 offshore farm, for instance, covers a larger area than the city of Emden, which has a population of around 50,000 people. The farm itself has 80 wind turbines, each with a capacity of 5 MW, generating a total of 400 MW.

Niilo Kantoniemi

Celebrating 40 Years of Enercon

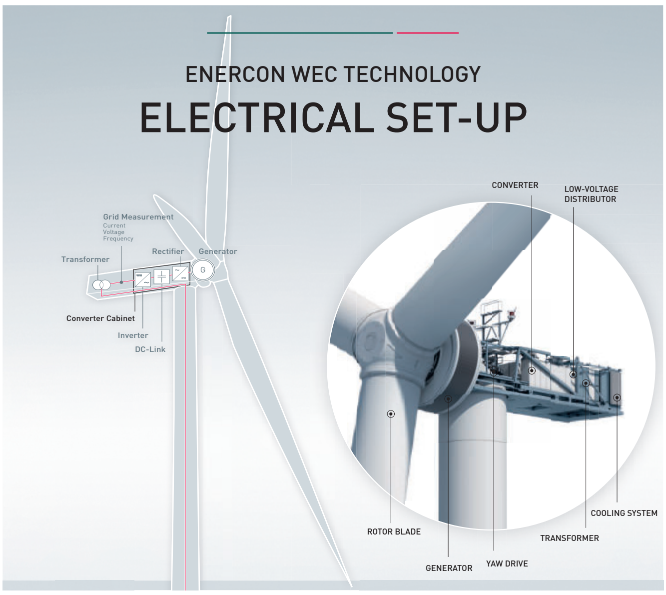
Enercon

The year 2023 was a turning point in Germany's electricity production, as, for the first time, wind power production exceeded the amount of electricity produced by coal. This made wind power the largest source of electricity in Germany with a 27% share. In the last ten years, wind power production has tripled, while coal-powered electricity has been reduced by half. [1] Hopefully, this trend will continue in the future.

Our excursion group visited Enercon GmbH, a German pioneer in wind turbine manufacturing.The company was founded in 1984, and since then they have installed over 32,000 wind turbines in more than 50 countries worldwide. At the same time, the nominal power of the turbines has increased from 55 kW of the E-15 and E-16 models to 7 MW of the E-175. The number following the letter 'E' represents the rotor diameter. So, the rotor diameter has increased over 10 times, and the nominal power over 100 times. Currently, more than 13,000 people are employed by the company worldwide.

We had the opportunity to tour the factory in Aurich, where new nacelles are assembled. All Enercon wind turbines are gearless direct-drive turbines with synchronous generators, which means the generator must have more poles making them larger. However, this design enables building turbines without gearboxes, so there are fewer mechanical losses and less maintenance needed. Earlier, these turbines were easy to recognize by their teardrop-shaped nacelles.

The latest nacelle model, the E-nacelle, differs from the previous models in that all the power electronics are now installed in the nacelle instead of the tower's base. Having the rectifier, DC link, inverter and transformer all in the nacelle makes testing easier and speeds up on-site installations. The generators are mounted separately in front



[1] International Energy Agency. Where does Germany get its electricity. Accessed: 27.9.2024 Available: https://www.iea.org/countries/germany/electricity#what-is-the-climate-impact-of-electricity-generation-in-germany

of the the nacelle, before the rotor hub. The generators are manufactured in Portugal, Poland, and Germany, and the rotor blades in Türkiye and Portugal. All these production sites are owned by Enercon.

"Enercon offers a range of services covering the entire life cycle of the wind turbine"

Seeing all the components and realizing the size of the entire nacelle certainly came as a surprise to every visitor. Although Enercon has invested in robotics, most of the steps in the production process are still done manually. These tasks are primarily electrical and more complex mechanical installations that cannot be completed by robots.

In addition to turbines, Enercon offers a range of services covering the entire life cycle of the wind turbine, including planning, implementation, financial services, repowering, and lifetime extension. There are numerous opportunities available in the field, and Enercon provides a strong start for students by offering internships and final thesis projects across various engineering specializations. Happy 40th Anniversary, Enercon! We wish you a windy future.

Petja Sereda

Energy Stored in Salt

Storag Etzel

Natural gas is still a key energy source in many continental European countries, including Germany. Approximately one fourth of the total energy used in Germany is supplied by natural gas, and over 720 TWh of natural gas was consumed in Germany in 2023, making it the largest natural gas user in Europe [1]. Gas is widely used across different sectors, the largest users being residential and industrial sectors with shares of 41% and 34%, respectively. The broad use of gas requires an extensive gas network with 530,000 km of pipelines and 255 TWh of storage capacity, which we learned more about on our third excursion day when we visited Storag Etzel in northwestern Germany.

As the name suggests, Storag Etzel is an Etzel-based company that mines, maintains, and leases underground salt cavern storage capacity for gas, oil, and, in the future, for hydrogen. The first caverns were mined in the 1970s to store oil, and the largest extension of the storage network was done in the early 1990s when a gas pipeline between Norway and Germany was commissioned. Nowadays, several countries store their critical gas reserves in Etzel, making it an important site for energy security.

The caverns are located close to the village of Etzel and 1,000 to 1,500 meters underground in a large salt dome. The salt dome is part of the Zechstein salt formations, which range from the east coast of Great Britain all the way to southern Germany, Poland, and Lithuania. The Zechstein salt formation was formed 5 to 7 million years ago when the Zechstein Sea evaporated, leaving behind the salt deposits [2.]. The salt can be used to store oil, natural gas, and even hydrogen, since it is non-porous enough and does not dissolve into these substances.

There are a total of 75 caverns at Etzel, of which 51 are used to store gas and 24 to store oil. Typical cavern volume ranges from 250,000 to 800,000 m^3, with a height of 300 to 500 meters and a diameter of 60 meters. The gas caverns have a total working gas capacity of 3.9 billion m^3, natural gas being strongly pressurized, and the oil caverns have a capacity of 11 million m^3. The lifetime of a cavern used for gas or oil storage can be up to 100 years. There is still potential to expand the cavern network in the salt dome with 15 million m^3 by mining 24 additional caverns.

The development of a new cavern is quite straightforward, but it is not the quickest process. First, the new cavern must be engineered, and a suitable location must be chosen. After that, the route to the salt dome surface is drilled, and the seawater pipeline needed for the mining is built. Then, the leaching (mining) process can begin. Seawater from the North Sea is pumped to the salt to dissolve it and form a cavern. The leaching process takes 3 to 4 years to complete, and the final shape of the cavern cannot be fully controlled, since it is impossible to predict where in the cavern the salt will dissolve. Therefore, all the caverns are unique in shape.

“Typical cavern volume ranges from 250,000 to 800,000 m^3”

Even though natural gas still plays a large role in continental European energy production, Storag Etzel is looking toward the future and the hydrogen economy. The H2CAST Etzel (H2 Cavern Storage Transition Etzel) project, launched in 2022, is refurbishing two of the caverns into hydrogen storages. The overall goal of the project is to prove the suitability of Etzel's salt caverns for hydrogen storage and demonstrate the feasibility of large-scale underground hydrogen storage.

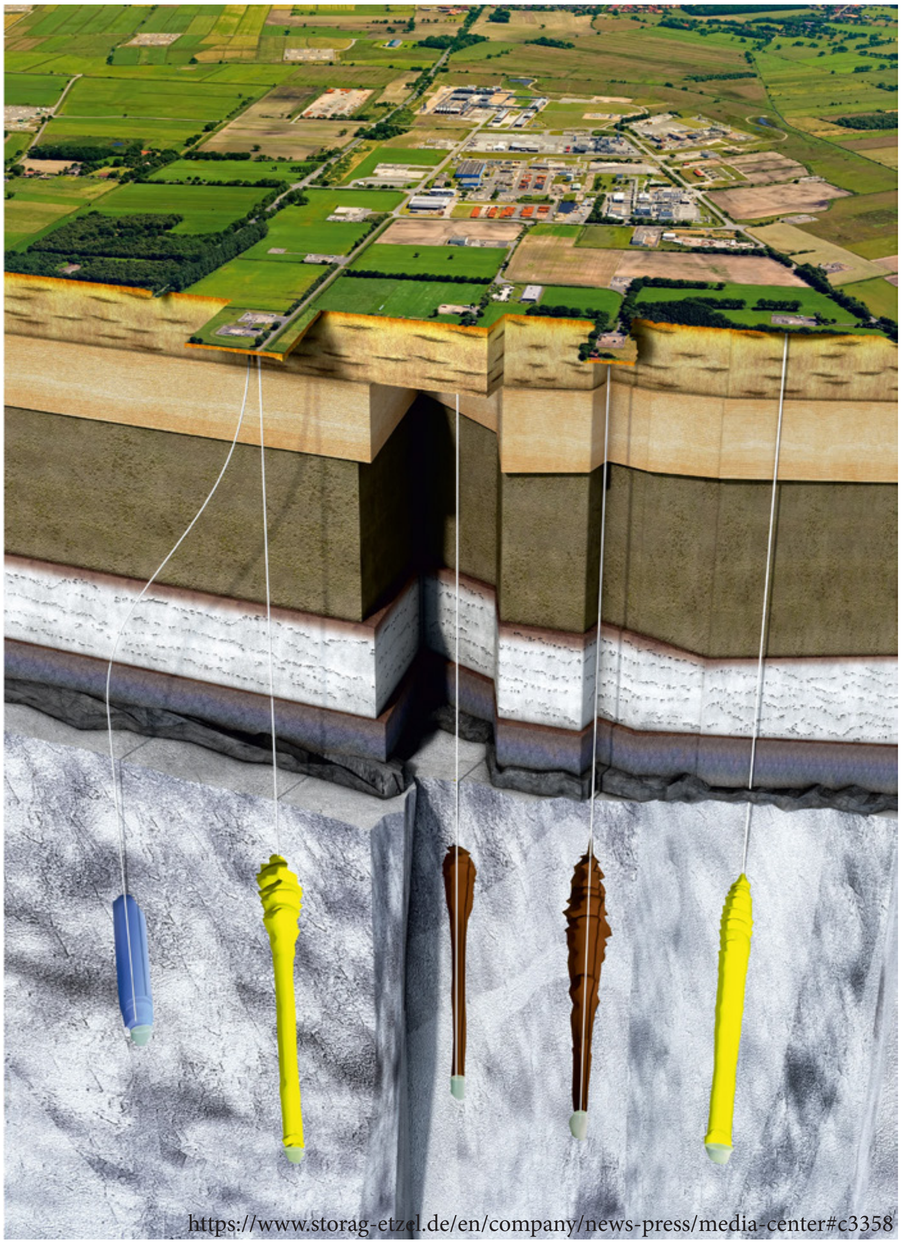
The project is set to finish by the end of 2026. At the time of our visit in August 2024, they had just completed the testing of all the equipment, including pipes, valves, and compressors, and hydrogen had been suc-

cessfully pumped in and out of the underground pipes. The next step in the project is to test filling the cavern with hydrogen, but there have been difficulties in finding a supplier for such a huge amount of hydrogen: the two caverns together can store up to 90,000 kg of hydrogen.

The future plan for the entire Etzel storage facility is to transform it into hydrogen storage and help create a strong hydrogen economy hub in the area. The H2CAST Etzel project is expected to pave the way for other hydrogen-related development projects in northwestern Germany and the Netherlands.

Eljas Almusa

[1] IEA, Natural Gas, Germany country page, available at: https://www.iea.org/countries/germany/natural-gas, Accessed: 24.9.2024
[2] The Geological Society of London, Zechstein Reefs, North Sea, Available at: https://www.geolsoc.org.uk/Policy-and-Media/Outreach/Plate-Tectonic-Stories/Zechstein-Reef, Accessed 24.9.2024



Cross-section view of caves visualizing the technology behind salt cavern storage.


Picture: Iiro Mikola

CURRENT STATE OF THE ENERGIEWENDE

Datteln 4 Power Plant

Our fifth day of the abroad excursion started with a one-hour travel to the town of Datteln, near Dortmund. The name of the town brings sorrowful associations for our group which were realized as we visited the infamous Datteln 4 coal power plant. The power plant project was initially started by E.ON in 2006, and later became known as an asset of Uniper, a company formed from separation of E.ON fossil-fuel assets Later, the majority of the Uniper's shares were procured by the Finnish company Fortum which was also responsible for commissioning the power plant in 2020 while many Finnish and German non-governmental organizations were loudly opposing the commissioning.

The power plant visit started with a presentation and discussion about the safety features and technical specifications of the plant. Our host was well-spoken which gave us an opportunity for an insightful discussion related to the Datteln 4 power plant. We heard of the impressive technical capabilities of the plant. Datteln 4 can produce power from a minimum output of 200 MW to a maximum of 1,100 MW with a flexibility of 50 MW/min, valuable in the German power system with a high share of wind and solar generation. The power plant plays a major role in the German railway power grid, providing 25% of the electricity for the separate, single-phase, 16.7 Hz railway transmission network. In addition, Datteln 4 provides 1 TWh of heat annually with the 380 MW heating power to the local district heating network and broader network covering large areas around Dortmund.

> **"Datteln 4 can produce power from a minimum output of 200 MW to a maximum of 1,100 MW with a flexibility of 50 MW/min"**

Before the power plant tour, we were instructed that photography was not allowed on the premises of the plant. This is of course, quite a typical rule. However, the reason was to avoid non-governmental organizations finding suitable locations to tie themselves as a protest. This might give a hint what the German public attitude towards fossil-fuel generation is (while also opposing nuclear power).

A lot to see. From the top, you could see far into the German lowlands.

The visit started with a crossing of a canal via a narrow bridge which also connects the power plant to the power grid and the district heating network. The first major component we saw was the rattling transformer station. After that, we walked through a hall containing the flue gas treatment section. From there we walked towards the cooling tower and to our surprise, we had the opportunity to enter inside. It was a unique experience to see how the cooling water rains from the tower to the bottom.

Next, we entered the plant building and saw the large steam generator, producing 2,900 t/h of supercritical steam. The energy is produced with 30 burners consuming altogether 360 tons of coal per hour. Unfortunately, the host did not seem to know the carbon emissions of the plant while knowing other parameters quite well. Nevertheless, the emissions are undoubtedly immense due to the high coal consumption. We also saw the turbine and the generator which can produce 1,100 MW of power. Generators in this power rating are uncommon, which impressed our group.

Finally, we went up to the roof of the power plant building which had a great view of the power plant and other nearby coal plants. After the tour, the host welcomed us to lunch in their canteen, which, to our surprise, served a hot vegan meal reminiscent of our student lunches back home. After the interesting visit to the Datteln 4 power plant, we continued our interrail trip towards Brussels.

Simeon Seppälä

TLS Energy Oy

Energiamurrosta pohjoisella länsirajalla

Pellon kaukolämpötuotanto näyttää muutaman vuoden päästä hyvin erilaiselta kuin tänään. Energiayhtiö TLS Energy Oy, yhdessä yhteistyökumppaniensa kanssa, valmistelee paikkakunnalla kaukolämmön sähköistämistä.

TLS Energy Oy on Tornionlaakson Sähkö Oy:n nuorin tytäryhtiö, joka lähtee valloittamaan energia-alaa inspiroituen vihreästä siirtymästä. TLS Energy Oy:n ensimmäisellä isolla hankkeella halutaan edistää kestävää kehitystä Pellon alueella, vahvistaa paikallisen teollisuuden toimintaedellytyksiä ja tukea myös Suomen matkaa kohti hiilineutraaliutta. Hanke vähentää päästöjä jopa 5600 CO_2-tonnia vuodessa.

– Kuopuksemme, TLS Energy Oy, tulee olemaan vahvasti mukana energiamurroksessa ja luomassa pohjoiseen uutta liiketoimintaa. Siihen tarvitsemme niin kokenutta kuin tuoreinta koulutusta saanutta työvoimaa. Opiskelijoiden ja juuri valmistuneiden mukana tulee yleensä ajankohtaisinta tietoa ja oppia, sekä innovatiivista ja aktiivista otetta tekemiseen. Siksi meillä myös annetaan heille mahdollisuuksia: vastuuta, mutta myös vapautta oman tehtävänkuvan sisällä, sanoo toimitusjohtaja Sakke Rantala.

Hankkeen myötä kiinteän polttoaineen lämpölaitoksen ja öljykattilalaitosten tuottama lämpö korvataan merikonttien sisään rakennettavien konesalien hukkalämmöllä. Hukkalämpö priimataan lämpöpumpulla korkeampaan lämpötilaan, ja lämpö siirretään kaukolämpöverkkoon. Ratkaisun joustava sähkönkulutus tukee myös sähköjärjestelmän tasapainoa. Hanke sai RRF-energiainvestointitukea työ- ja elinkeinoministeriöltä.

Tornionlaakson Sähkö Oy:n konserniin kuuluu TLS Energy Oy:n lisäksi sähköverkkoyhtiö TLS Verkko Oy. Emoyhtiö omistaa myös tuotanto-osuuksia energiatuotannon eri muodoista.

No Transition Without Transmission!

ENTSO-E

“Massive investments are needed in the power system for the EU energy and climate targets to be reached”

Friday morning dawned grey, fitting the bureaucratic theme of our visit to Brussels. After a hearty hotel breakfast, the next item on our schedule was a visit to ENTSO-E, which stands for the European Network of Transmission System Operators for Electricity. Consisting of 40 member Transmission System Operators (TSOs) representing 36 countries, ENTSO-E is responsible for the coordinated and secure operation of Europe’s 500,000 km of electric grids, always preparing for the future while managing the present. Founded in 2009, ENTSO-E employs around 200 people representing 35 nationalities, with 160 of them being ENTSO-E’s own employees and about 40 people working as contractors or secondees from member TSOs.

ENTSO-E’s main responsibilities include long-term grid planning studies like the Ten-Year Network Development Plan (TYNDP) and the Offshore Network Development Plan (ONDP). ENTSO-E also makes security of supply and adequacy analyses, such as the European Resource Adequacy Assessment (ERAA), and the development and implementation of technical rules for the TSOs. These extensive analyses, along with other expert contributions from ENTSO-E, are used by EU policymakers to make informed decisions regarding the future of Europe’s electricity system, affecting 520 million citizens. The extensive analyses and policy work are worth the effort, as the energy transition requires so much resilience and flexibility from electric grids, something that has been noticed by the policy makers as well. Fortunately, electric grids are now recognized as the backbone of the entire energy transition, largely thanks to the experts at ENTSO-E!

The Ten-Year Network Development Plan (TYNDP) is a biannual study focusing on grid planning future scenarios. The base scenario of the 2024

TYNDP aggregates the National Energy and Climate Plans (NECPs) and national strategies to map the investment needs in grid infrastructure across Europe. The latter two are deviation scenarios, with 2030 as the common starting point for all scenarios. The 2024 TYNDP scenarios align with the EU's 2030 energy and climate targets, as well as the 2050 climate neutrality objective, making it more of a 30-year outlook than a ten-year plan. TYNDP identifies projects of common interest that provide the greatest overall system benefits and helps facilitate funding and permits for these projects. The projects are selected through a cost-benefit analysis, with cross-border projects being prioritized, as TSOs are responsible for country-specific investments. Some projects also involve third countries, such as North African countries.

The results from ENTSO-E reports have a clear, consistent message: massive investments are needed in the power system for the EU energy and climate targets to be reached. For instance, 403 billion euros need to be invested in 54,000 km of new offshore transmission infrastructure to enable the estimated 500 GW of offshore renewable electricity generation. However, our excursion hosts emphasized that annual investments of 6 billion euros could generate 9 billion euros in annual social welfare benefits across Europe.

The current electricity market is far from perfect. Renewables, due to their high investment costs, require clear signals of long-term profitability. The cannibalization effect of renewables, especially evident in Finland, is the opposite of that. Accelerating renewable energy development requires effective and well-designed support schemes. Maximum energy production may not lead to maximum value, and negative electricity prices should be a clear indicator of that. The weather dependency and variability of renewable generation require complementary power system flexibility. This can be enabled through interconnections, market integration, flexible generation, demand response, and storage technolo-

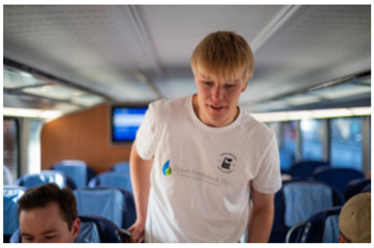
gies. Investments in balancing capacity are necessary, and capacity mechanisms will likely be needed in many European countries. ENTSO-E has been assessing these and many other issues in their ERAA reports, seasonal outlooks, and market design studies. Their work is ever more important with the difficulties the power system will face in the coming decades. This is also promising news for energy engineering students, as future energy system experts will surely be needed in the coming years!

Onni Tikkanen

Trains, Trains, Trains!

During the excursion, we travelled over 2,600 km by train! Here are some moments captured on the go.




ICE 15
24
13 04
Nouveau terminus
Köln Hbf
Arrivée dans 61 min
12:15 14:05
Voie
4
Terminus du train : Köln Hbf
Veuillez descendre du train à l'arrivée en gare.
Merci d'avoir choisi la Deutsche Bahn pour votre
voyage. Au revoir !







It's Not Just Wind Power We Need More of, but Also Grids

WindEurope

Our second excursion in Brussels headed to WindEurope, an association promoting the use of wind power in Europe. They have over 600 members from the entire wind energy value chain, including wind turbine manufacturers, component suppliers, power utilities, wind farm developers, financial institutions, and universities. WindEurope works closely with political bodies and their main focus is on advocacy work, but they also share information. Approximately 80 people work at WindEurope.

As soon as the excursion began, we heard a familiar phrase from our previous excursion at ENTSO-E: no transition without transmission. WindEurope's message was that the main bottleneck to the deployment of new wind energy projects is now in electricity grids. A huge amount of renewable energy projects are waiting for grid connection in Europe, and without critical grid investments, Europe cannot deliver its energy security and climate targets. It was surprising that during the excursion, the focus was less on wind energy itself and more on the future needs of the grid. This highlights how interconnected energy markets are and how important it is to consider the bigger picture in the energy transition.

We discussed three main challenges for the grid development: financing, politics and supply chain issues. According to WindEurope, annual grid investments should double. The EU Commission's Action Plan for Grids states that over 580 billion euros of new investments are required by 2030 to upgrade Europe's grids. When it comes to politics, there is a huge need for proactive grid planning and more efficient grid permitting processes. In addition, when different countries have different requirements based on their level of renewable integration and system requirements, better coordination is needed among stakeholders, as well as between policymakers and regulators both the EU and national levels. This includes, for example, standardised implementation of network codes across the EU. When looking at supply chain issues, bottlenecks are usually caused, for example, by long lead times for grid components, increasing raw material prices and divergences in product specificities.

"The main bottleneck to the deployment of new wind energy projects is now in electricity grids"

At the end of our excursion, we were happy to hear that WindEurope does a lot of cooperation with students. They advocate for more energy engineering students and also other related areas. On their website, they offer a market intelligence platform where students can access free data, such as statistics and reports. Every year, they organise a conference where students can network, get to know the industry, and explore career opportunities. WindEurope also offers sponsorships for conferences, with the next one taking place in Copenhagen in April 2025 – an opportunity worth keeping in mind!

Jenni Leinonen

It is hard to say no when the excursion host offers a cup of coffee.

The Swiss Energy Puzzle: Hydropower, Nuclear Phase-Out, and Renewable Expansion

Country Overview

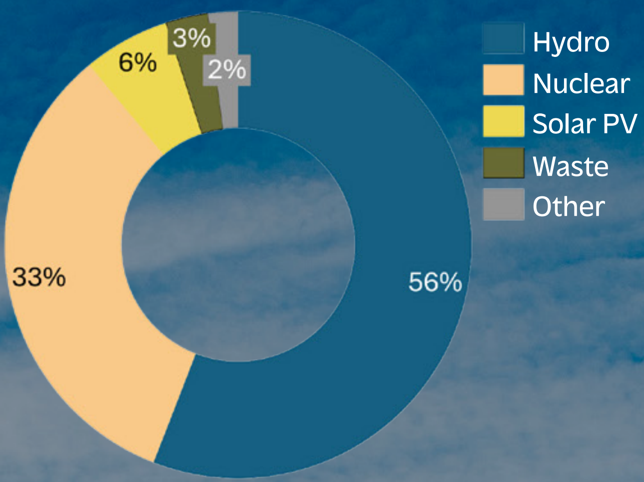
Switzerland is renowned for its expensive watches, chocolate, and the Alps. In addition to these, Switzerland is also known for one of its most significant natural resources: hydropower. Thanks to the country's mountainous terrain and high levels of annual rainfall, hydropower is Switzerland's largest source of renewable energy, accounting for 90% of its all renewable energy generation and 14% of total energy supply [1]. During our excursion, we visited both a typical run-of-river power plant, the Eglisau-Glattfelden hydropower plant, and the exceptional Nant de Drance pumped storage hydropower plant, located in the heart of the Alps. Only 4.2% of Switzerland's hydropower is generated by pumped storage plants, with the rest coming from run-of-river and conventional storage power plants [2].

Although Switzerland's electricity production is nearly carbon neutral, thanks to its significant reliance on hydropower and nuclear energy, oil still accounts for 33% and natural gas for an additional 10% of the country's total energy supply [1]. Unlike many other countries, Switzerland has almost entirely phased out coal, with the high oil consumption being largely attributed to the transport sector.

Nuclear power also plays a key role in Switzerland's energy mix, providing 33% of its electricity generation. When combined with heat production, nuclear energy accounts for 28 % of the country's total energy supply [1]. Following the 2011 Fukushima nuclear disaster, Switzerland, like Germany, decided to halt the licensing of new nuclear power plants and begin decommissioning existing ones [3]. However, unlike Germany, Switzerland has been slower in implementing these plans. So far, only one plant has begun the decommissioning process, while the others remain operational until the end of their technically safe lifespans [3]. While this more measured approach seems prudent, it raises the question of how Switzerland plans to replace the energy currently provided by nuclear power while still achieving carbon neutrality.

One observation our group made as soon as our train crossed the Swiss-German border was the noticeable absence of wind turbines in the Swiss landscape. Currently, Switzerland has nearly 40 large wind power plants, primarily located in the southern part of the country [4]. However, we saw only a few scattered turbines along our route. Wind power contributes a mere 0.4% of Switzerland's renewable electricity generation [1]. According to the Swiss Federal Office of Energy, wind power has untapped potential and could play a larger role in increasing the share of renewables in the country. Wind energy is especially valuable for balancing renewable energy generation, as two-thirds of wind power is produced during

Switzerland electricity generation by source, 2023



the winter months, when wind conditions are more favorable. In contrast, hydro and solar power generation peak during the summer, making wind energy a key resource for maintaining a balanced energy system. [4]

In addition to boosting renewable energy, the Swiss government aims to meet its emission reduction targets by improving energy efficiency across all sectors, in both energy supply and consumption. While these efforts require significant investments, plans are underway to support this transition. However, it remains to be seen which approaches will prove most effective in driving Switzerland's energy transition. [5]

Emma Kuula

Picture: Lauri Heroja

[1] IEA. Country overview: Switzerland. cited: 30.9.2024. Available: https://origin.iea.org/countries/switzerland
[2] Swiss Federal Office of Energy SFOE. Hydropower. last updated: 2.5.2024. cited 30.9.2024. Available: https://www.bfe.admin.ch/bfe/en/home/supply/renewable-energy/hydropower.html/
[3] Swiss Federal Office of Energy SFOE. Nuclear energy. last updated: 2.7.2020. cited 30.9.2024. Available: https://www.bfe.admin.ch/bfe/en/home/supply/nuclear-energy.html
[4] Swiss Federal Office of Energy SFOE. Wind energy. last updated: 15.12.2023. cited 30.9.2024. Available: https://www.bfe.admin.ch/bfe/en/home/supply/renewable-energy/wind-energy.html
[5] Swiss Federal Office of Energy SFOE, Media and Political Affairs Division. 18.1.2018. Energy strategy 2050 once the new energy act is in place. Available: https://www.bfe.admin.ch/bfe/en/home/policy/energy-strategy-2050.html/

Red Tiles and Skylights – Is It Designed by Aalto? Wait... No, This Is Switzerland!

Eglisau Hydropower Plant

There is a 104-year-old hydropower plant located right at the border of Switzerland and Germany. This old but well-preserved facility has a nominal power of 43.4 MW, making it a mid-size hydropower station along the river Rhine, where the largest hydro station by capacity is the 148 MW Iffezheim [1]. The Eglisau plant has six Kaplan turbines, each with the capacity of 6.7 MW. The power plant is dimensioned for a maximum water flow of 2,700 cubic meters per second, but when we were visiting, only 1,000 cubic meters per second was flowing through due to low rainfall in the last few days.

The turbine hall of the Eglisau hydropower plant.

The Eglisau hydropower plant had recently undergone renovations that cost approximately 300 million francs. The amount of money could have paid for a couple of new power plants, but this one is on the list of protected monuments. The preserved architecture resembled a bit of Alvar Aalto's production with the red-tiled walls and indirect skylights in the ceilings. The history also tells that the locals used to come warm up on the balcony of the turbine hall during cold winters, when the houses in the area did not have central heating. It must have been quite majestic scenery to watch the river flow and hear the turbines roar during those days - nonetheless, it still amazed us with its precise functionality to this day.

The day of our visit happened to be a special maintenance day for the dam. Sometimes, heavy rainfall causes flooding, which carries whole trees to the dam. However, the dam gates are not designed to let through such large and oddly shaped objects. As a result, the torn metal had to be repaired, and we got to see the massive crane in action, effortlessly lifting dam gate blocks weighing several tonnes from the ground. It was impressive machinery work and yet another thing one does not see on the university lectures. Another impressive machine at the site was the fish lift. Exactly as it sounds, it is a lift that waits for fish to come and then lifts them to the other side of the dam. However, the fish must not be in a rush, as the lift only operates once an hour.

[1] Enbw. 2024. Iffezheim Rhine power plant. Available: https://www.enbw.com/company/the-group/energy-production/new-buildings-and-major-projects/iffezheim_staustufe/ (accessed 30.9.2024)

"The locals used to come warm up on the balcony of the turbine hall during cold winters

The excursionists also got the chance to learn about Swiss work life and freetime from Riku Merikoski. Merikoski works as an electricity market analyst for Axpo in Switzerland – a career path many of us are certainly interested in. We put together some of the insights he shared with us on the next page.

↑ Giving some Finnish presents and sweets to Mr. Merikoski, who moved from Finland to Switzerland to work at Axpo Group.

Sonja Nurmiainen

Eight facts you should know about Switzerland

1. Salaries are higher than in Finland, but taxes are lower.

2. However, water in restaurants costs 6 € per glass, and daycare for children costs 2,500 €/month.

3. Switzerland is divided into 26 cantons that hold most of the legal power, and for example taxation practices vary among each.

4. The Swiss like to vote often, but the voting is not always put in context. People are just asked, e.g., "Would you like to have a raise in the pensions - yes or no?" And people will obviously vote yes, but nobody has yet considered how the raise is going to be paid for.

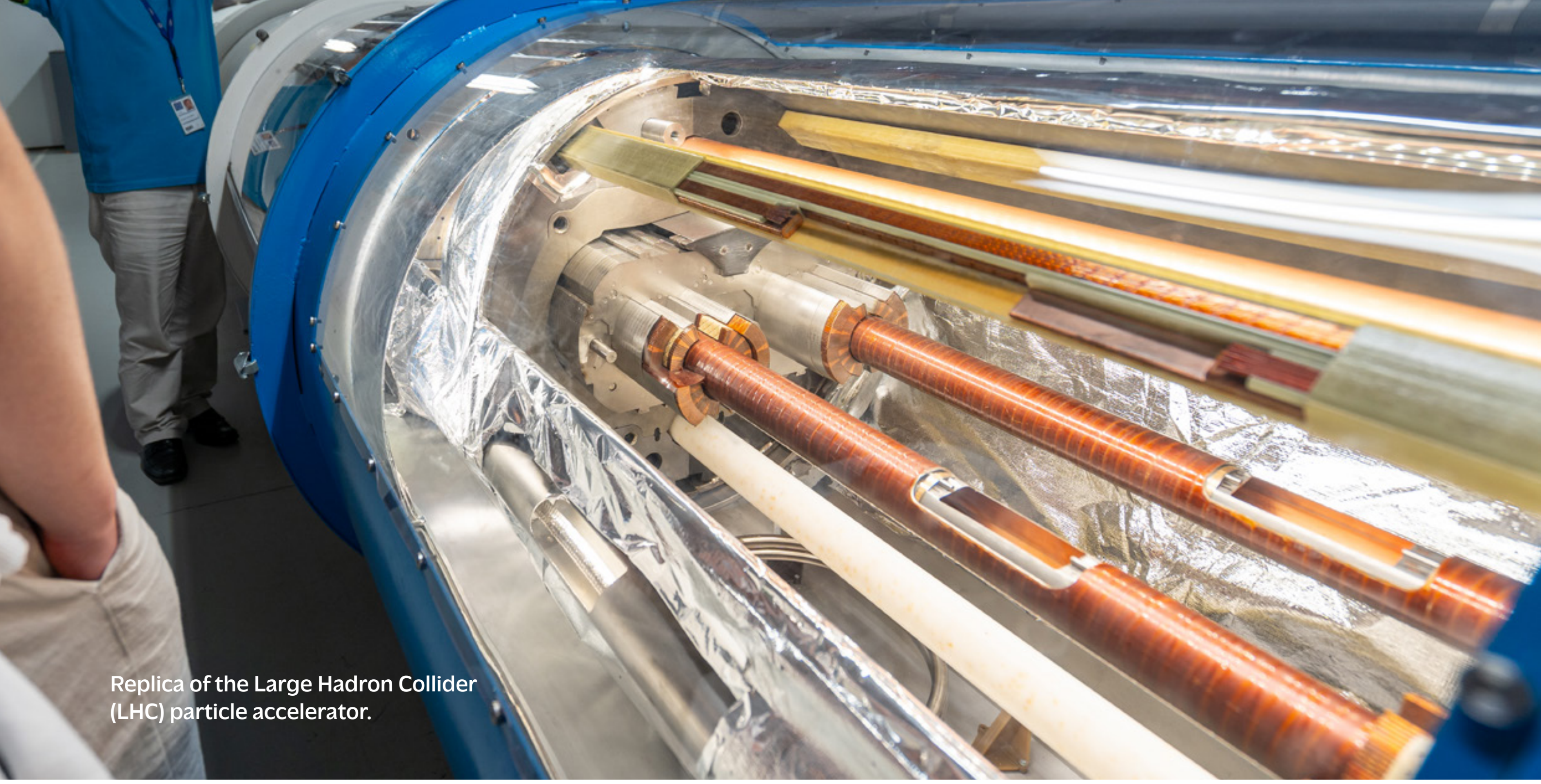
5. Switzerland is an extremely safe country, and it has amazing public transport. For example, we were able to easily reach the Eglisau hydropower plant, as a train to the small nearby village of Zweidlen runs once an hour.

6. Four official languages are spoken in Switzerland, and it is much easier to make contact if you speak the region's language.

7. Swiss chocolate is delicious, but some could argue it is too sweet for the Finnish taste buds.

8. Despite being a highly modern society, the full-time employment rate of Swiss women is among the lowest in Europe.

Switzerland is a highly mountainous country, with 70% of its territory covered by mountains. The Swiss flag waves in the winds of the Bernese mountains. Picture: Lauri Heroja.



Replica of the Large Hadron Collider (LHC) particle accelerator.

CERN: Uncovering the Secrets of the Universe

CERN

Founded in 1954, CERN (Conseil Européen pour la Recherche Nucléaire) is the world's largest research center for particle physics. It focuses on basic research, developing new technologies, and applied physics. The most famous piece of equipment at CERN is the world's largest particle accelerator, the Large Hadron Collider (LHC), which has a circumference of 27 kilometers.

The LHC is mainly used to accelerate protons, but also heavier ions, such as lead ions. The accelerator can reach collision energies of up to 8 TeV (teraelectronvolt), which enables research of previously unseen phenomena.

The acceleration of protons happens in multiple phases: first, the linear accelerator, then the Booster, Proton Synchrotron, Super Proton Synchrotron, and lastly the LHC. The protons are already accelerated up to 0.5 TeV before injection into the LHC. The LHC has thousands of magnets along its length. Over 70% of these are dipole magnets that are used to keep the protons on their circular trajectory. The rest are quadrupole magnets, designed to adjust the proton beam before the collision. The protons circle the LHC at speeds of up to 99.999999% the speed of light, which corresponds to more than 3000 laps per second around the ~85 km pipeline. These collisions occur in four different experiments: ATLAS, CMS, LHCb, and ALICE.

The most famous accomplishment at CERN is the discovery of the Higgs boson in 2012, made in the ATLAS and CMS experiments. This finding confirmed an important part of the Standard Model and was the main motivator for building the LHC. The ALICE experiment studies quark-gluon-plasma, which was the state of matter immediately after the Big Bang. The LHCb experiment, on the other hand, investigates CP-violation, which can help our understanding of the imbalance between matter and antimatter in our universe. There happened to be a Finnish researcher at CERN working on this very topic, and that same scientist gave a tour to half of our group.

Even though incredibly high energies are achieved in the LHC, plans have been made for an even larger particle accelerator, the Future Circular Collider (FCC), for the research of yet unseen reactions. The budget for the FCC would be a staggering 13 billion euros. The budget, however, faces some challenges, especially in Germany, which is the largest financial supporter of CERN.

CERN isn't just a physics research center, multiple innovations in technology have their roots there. For example, the internet, touch screens, and superconducting magnets have all started from research done in CERN.

Finally, CERN is also a unique site for researching antimatter. There is a facility called the Antimatter Factory, where studies are conducted on, for example, how gravity affects antimatter (in the same way as regular matter so far). Even though the most groundbreaking discoveries such as the Higgs boson have already been made, scientists at CERN continue the research on unknown phenomena, as particle physics is in many ways just at the beginning of unraveling the mysteries of the universe.

Alex Savolainen

The internet, touch screens, and superconducting magnets have all started from research done in CERN

Picture: Iiro Mikola

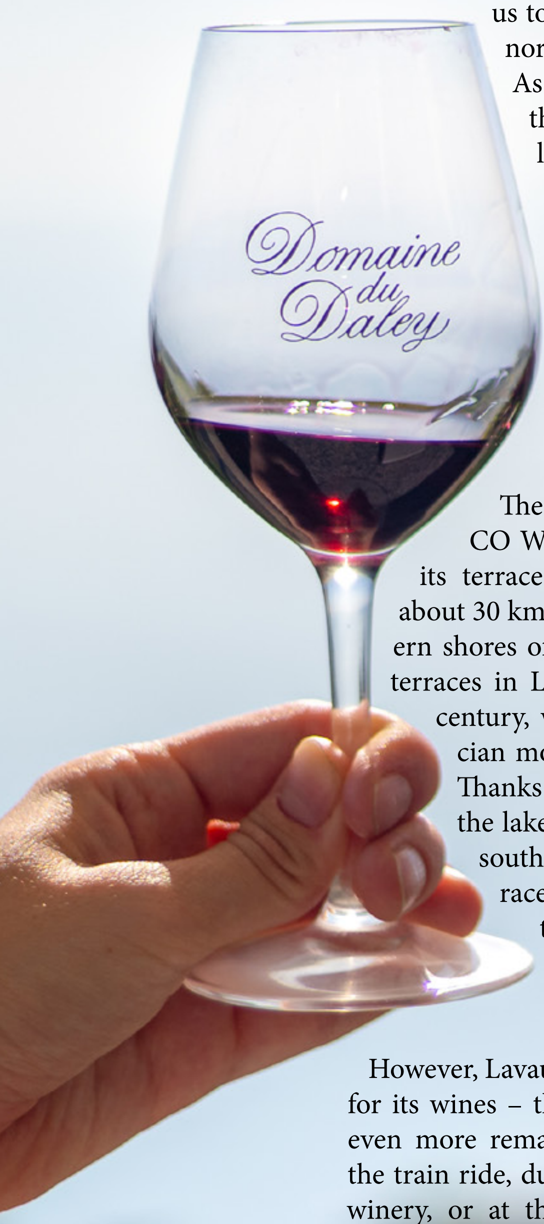
Wines and Views

– A Perfect Pairing

Wine tasting at Domaine du Daley winery, Lavaux vineyards

“The first vine terraces in Lavaux date back to the 11th century”

Visiting a winery was one of the must-do free-time activities during our journey through some of the best wine regions in Europe. Therefore, after visiting CERN in Geneva, we hopped on a train that quickly took us to the Lavaux vineyards on the northern shores of Lake Geneva. As soon as we arrived and saw the stunning views across the lake, we knew we had come to the right place. As a bonus, a hotel near the train station kindly allowed us to store our luggage there during our winery visit – free of charge! Perhaps it was out of sympathy for the poor students traveling through Switzerland.



The Lavaux region is a UNESCO World Heritage Site, known for its terraced vineyards. It stretches for about 30 km along the south-facing northern shores of Lake Geneva. The first vine terraces in Lavaux date back to the 11th century, when Benedictine and Cistercian monasteries controlled the area. Thanks to the reflection of the sun on the lake and the heat retained by the south-facing stone walls of the terraces, the region’s climate is said to have a Mediterranean character – and that’s exactly how it felt during our visit!

However, Lavaux is not only famous for its wines – the scenery might be even more remarkable. Whether on the train ride, during the walk to the winery, or at the winery itself, the views of Lake Geneva brought out recurring sighs of admiration: A calm, turquoise lake. Lush, rolling vineyards. Misty, rocky mountains, and a cloudless sky. It’s no wonder, after all, that the monks settled right here to cultivate wine.

We had the pleasure of savoring the region’s wines at Domaine du Daley winery, in the heart of Lavaux. Like the vineyards, the winery itself has a long history – dating back even further than our 58-year-old Lämpövoimakerho. Our friendly guide proudly mentioned that Domaine du Daley was established as early as 1392. After a brief history lesson, we finally got some wine for our bone-dry throats.

Most of the grapes grown in the Lavaux region are of the original green variety, Chasselas. Fittingly, the first wine of the tasting was a 2022 Chasselas white, the winery’s signature wine, which turned out to be the local star of the tasting. It was light, dry, and subtle. Chasselas wines are traditionally paired with Raclette and Fondue, but it was also a perfect match for the hot day. With refreshing glasses in hand, we began our small winery tour, starting with the ground-floor wine production facilities before moving on to the wine cellars.

In a new wine cellar, we discovered small red wine barrels made of French oak, where the red wine rests and absorbs the aromas of the wood. In an ancient, original wine cellar, we found large Swiss oak barrels, decades old, in which the white wine matures, typically for a year. After the tour, we were served glasses of rosé wine,

We were given a brief introduction to the history of the winery and the wines we were about to taste.

Picture: Iiro Mikola

which – with its exceptionally oaky flavor – left us with a lasting taste memory of the wine cellars.

In addition to wine tasting, we were educated a little. Among the many things we learned and discussed were the meanings of terms like "tannic", how to hold a wine glass correctly, and the differences in how white, red, and rosé wines are made. Younger travelers learned from their older peers how to taste wine properly. Thus, the last wine served to us – an excitingly peppery red made from a blend of two grape varieties – was savored in the proper manner: sniff, swirl, sniff, taste, voilà!

Jaakko Kivekäs

Travelers' comments on the wines

White

"Jackpot after the sweaty hike"

"Tasty, but maybe even too mild"

"Very satisfied"

"Really easy to drink"

"Fresh"

Rosé

"Not my favourite"

"The bad features of red and white wine combined"

"Eventually, not a delight"

"Personal favourite because of the colour"

"Very satisfied"

"Quite good"

Red

"Peppery; would have needed a pepper steak"

"Fave"

"Sweetness and tannins from two different grapes"

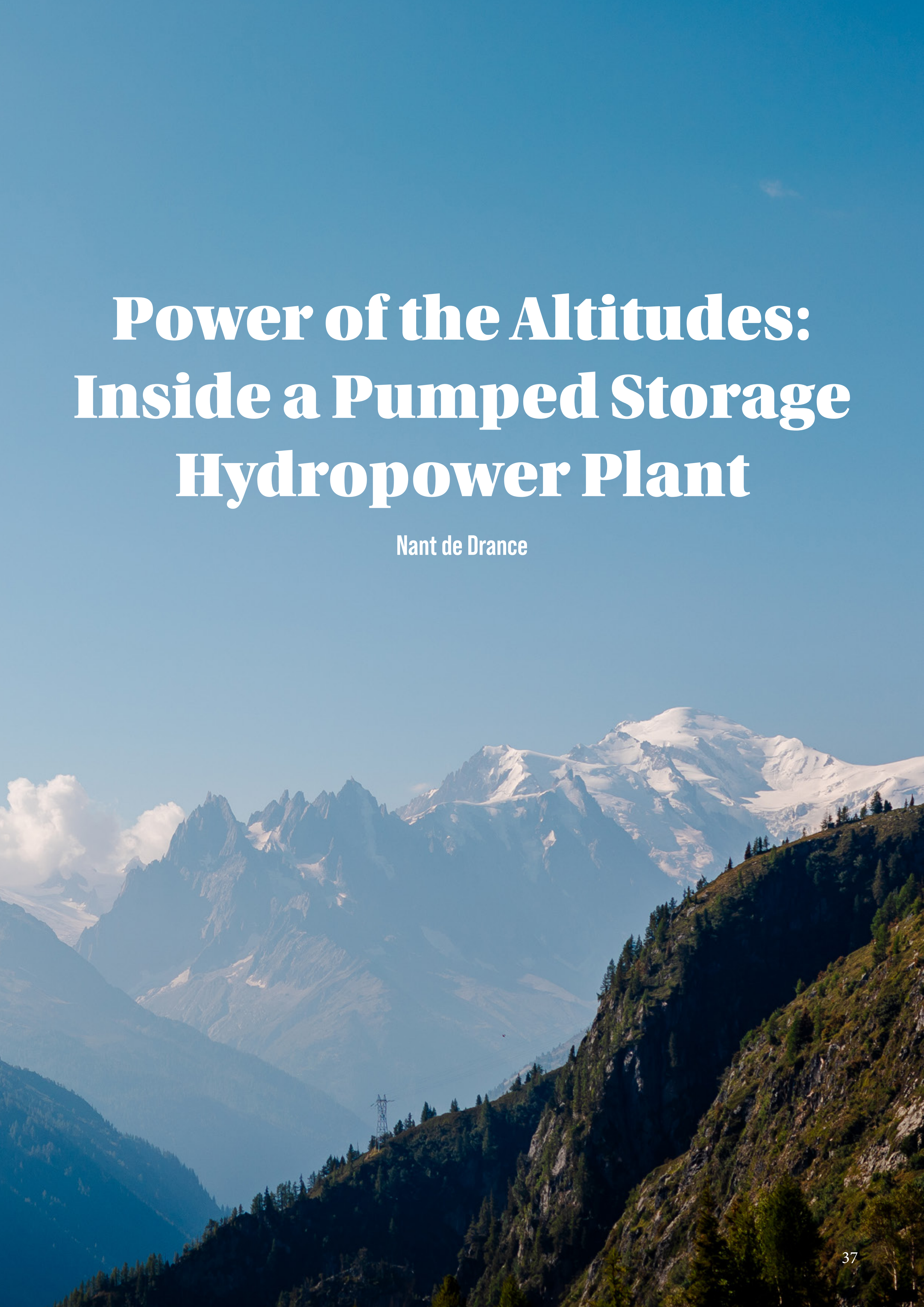
"I wasn't satisfied"

"Tannic, tastes like a barrel"

"Really delicious"

Power of the Altitudes: Inside a Pumped Storage Hydropower Plant

Nant de Drance



We had been in Switzerland for three days, and now we were finally getting the real Swiss experience: waking up early in the middle of the mountains. Locals do this often, whether it's to go to work or to start a hike. We, on the other hand, were ready at Martigny train station at 7:00 AM, heading to Nant de Drance, a pumped storage hydropower plant nestled in the highest mountains of the Alps. At the station, we checked our direction on Google Maps, which pointed us toward the mountains. As it turned out, the map was right — the train passed through a mountain wall. For us engineers, this kind of engineering masterpiece, combined with the spectacular mountain views, made the train journey feel like it lasted only a moment.

Under the morning mountain sun, we arrived at our destination – Le Châtelard-Frontière. As the French word *Frontière* means 'border,' the train station is located at the border of Switzerland and France, in a valley that eventually leads to Chamonix. Our guide, the director of the Nant de Drance construction project, was waiting for us at the station and began the excursion with a presentation about the project. We were told about the history of the project, the fascinating technology, and its current operation.

"At Nant de Drance, the technology is built inside the mountains"

Nant de Drance is a pumped hydro storage plant. The working principle of pumped storage hydropower is simple: it produces electricity when demand is high, and pumps water to the reservoirs when electricity prices are low. Nant de Drance operates with two reservoirs: Lac du

Vieux Emosson, which is located higher at 2,225 m, and Lac d'Emosson, a few hundred meters lower at 1,930 m. When the plant produces electricity, water runs from Lac du Vieux Emosson through turbines to Lac d'Emosson. The plant has six turbines and a maximum power output of 900 MW, roughly the same as the nuclear power plant Olkiluoto 2 in Finland.

The construction of this 2-billion Swiss franc power plant took 14 years, and began operations in the summer of 2022. One challenge during construction was the snow. At that altitude, the dams experience long winters with snow depths reaching several meters. Our guide mentioned that professional mountain guides were employed to assess avalanche risks and ensure worker safety.

One of Nant de Drance's key advantages is its flexibility: It can switch from full-capacity pumping to full-speed turbine operation in less than five minutes, and switch back in under ten minutes. Thanks to these impressive capabilities, it can produce electricity exactly when needed, making it a crucial part of Switzerland's power system.

Inside the turbine hall.

After the presentation, it was time to visit the power plant. At Nant de Drance, the technology is built inside the mountains; only the dam and reservoirs are visible from the outside. This means there is an 18 km road network within the mountain. First we entered through two massive doors and it was fun to realize that we actually had hundreds of meters of rock above us. We began driving through a tunnel to visit different parts

A group photo on top of the lower dam, with Mont Blanc (4,806 m) visible in the background. ↑

A 9-meter-diameter penstock equipped with disc valves. ↗

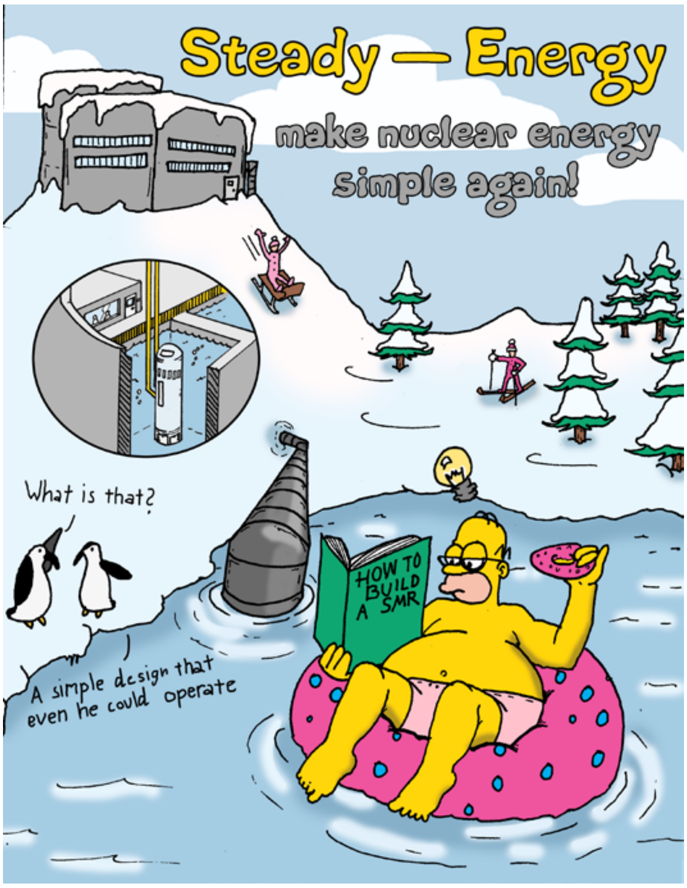
A turbine in action; during our visit, five out of six turbines were producing electricity. →

of the plant. Due to the temperature difference, fog had formed in the tunnels, adding a spooky and unique atmosphere to the drive.

During our tour, we visited the key facilities of the plant, including the electricity distribution center, the turbine hall, and a 9-meter-diameter pipe with disc valves. At that time, not all the turbines were running, as there was no demand for full power. After an hour inside the tunnels, we finally emerged back into the sunlight. Only then did we realize we had ascended 800 meters through the tunnels by car.

Nant de Drance is not just a power plant; the area is also a popular destination for outdoor enthusiasts to enjoy stunning mountain views. We stopped at the larger dam, where the turquoise waters of Lac d'Emosson lie on one side, and the highest mountain in the Alps, Mont Blanc (4,806 meters), towers on the other. The dam itself is enormous – a 180-meter wall set against the stark landscape, creating a breathtaking experience. After admiring the views and taking group photos, it was time to head back down. With the train about to depart, we decided to take a winding road from 1,930 meters back to the train station at 1,116 meters.

Lauri Heroja



The Emosson Dam, a 180-meter concrete wall, is an impressive sight to see in real life. If you have a fear of heights, it's better not to look down!

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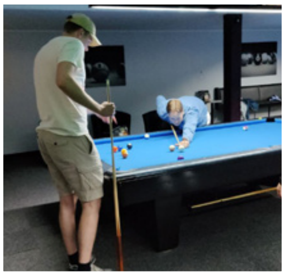
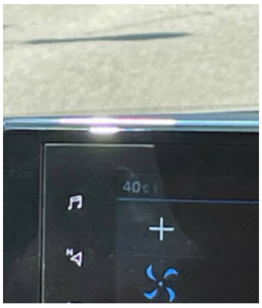
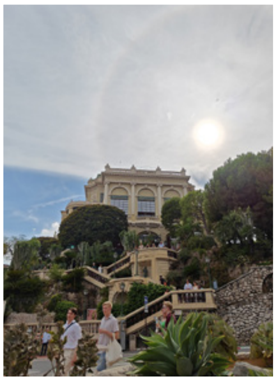


Scenic Views and Relaxed Vibes

Between excursions and traveling, we made the most of our free time!



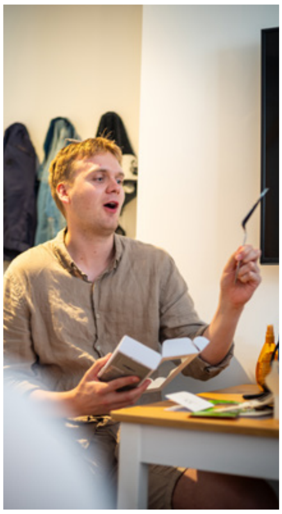










THE FUTURE IS EUROPE






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Liberté Égalité Énergie Nucléaire

Country Overview

France is globally recognized for its cultural contributions for cuisine, art, and fashion. Possibly less well-known, but equally significant, is its distinctive energy system. France's approach to energy, much like its cuisine, balances tradition and innovation. The country's heavy reliance on nuclear power, combined with a growing focus on renewable energy, reflects its commitment to sustainability and energy independence. France was the last country we visited during our abroad excursion of 2024 and, of course, we went there to see the French nuclear expertise. Our schedule included visits to the Bugey nuclear power plant (page 47) as well as ITER (page 50), before we headed to the French Riviera to wind down after the two intensive weeks (page 53).

Like the baguette on a French meal, nuclear energy forms the basis of the French energy system. In response to the oil crises in the 1970s, France made a strategic decision to heavily invest in nuclear energy to reduce its dependence on foreign oil [1]. As a result, around 65% of the country's electricity is generated by nuclear power today, making France one of the most nuclear-reliant nations in the world [2]. This extensive use of nuclear power has allowed France to maintain relatively low carbon emissions compared to other industrialised nations. The country also exports electricity to its more fossil-fuel-reliant neighbours, including Germany. In 2014, France set a target to reduce the share of nuclear electricity to 50% of all generation by 2025. The target year was later postponed to 2035, and then cancelled in 2023, as France now considers nuclear a must-have resource to reach its carbon neutrality targets by 2050 [1].

Despite its reliance on nuclear energy, France is increasingly investing in renewable energy. In 2023, renewable energy accounted for roughly 27% of total electricity production in France [2]. Hydropower, supported by the country's abundant river systems, plays an important role. Regions with strong winds, particularly along the northern coast, have seen significant investments in wind energy, while the sun-soaked southern regions are ideal for solar installations [3]. While nuclear power will continue to be a significant part of the country's energy mix, the growing contribution of renewable sources will help France meet its climate goals.

Even though the emission intensity of French electricity is low, France still uses a lot of fossil fuels, mainly oil and natural gas, in its overall energy supply. Oil, mainly used in the

French hydropower: picture of the Lac de Sainte-Croix reservoir, located in southern France.

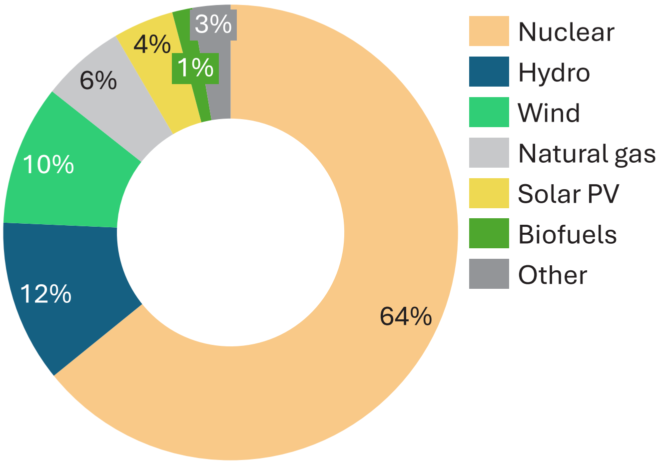
transport sector, and natural gas account for 30% and 14% of France's total energy supply, respectively. Natural gas is used primarily for residential heating and cooking, but also in the industrial sector in chemical and fertilizer production. Only 7.6% of French electricity generation in 2023 was fossil-based, with natural gas contributing 6%.

Even though France's energy system is less reliant on fossil fuels than some of its neighbours, their energy security is far from perfect. In 2022, France suffered multiple simultaneous energy-related crises. The Russian invasion of Ukraine, discovery of corrosion damage in multiple French nuclear power plants, and historical droughts impacting hydropower across Europe put the French energy system, along with the whole continental European energy system to test [4].

Additionally, France's reliance on nuclear fuel imports poses another energy security risk. In 2022, France procured its nuclear fuel from Australia, Kazakhstan, Uzbekistan, Namibia, and Niger, the last of which experienced a military coup in 2023. This raised questions about France's energy independence during crises, as the aforementioned 65% of its electricity production relies on imported nuclear fuel [5]. However, it is important to note that France also uses recycled nuclear fuel, known as MOX, which accounts for 17% of its electricity generation [1]. Nevertheless, when it comes to energy security, the old saying holds true for France as well: don't put all your eggs in one basket.

Onni Tikkanen

France electricity generation by source, 2023



[1] World Nuclear Association. Nuclear Power in France. Available at: https://world-nuclear.org/information-library/country-profiles/countries-a-f/france
[2] International Energy Agency (IEA). France. Available at: https://www.iea.org/countries/france
[3] RTE France. 2023. Bilan électrique France 2023 - Un nouvel équilibre pour le système électrique. Available at: https://www.rte-france.com/actualites/bilan-electrique-france-2023-nouvel-equilibre-systeme-electrique
[4] RTE France. Annual Electricity Review 2022. Available at: https://analysesetdonnees.rte-france.com/en/electricity-review-keyfindings
[5] Le Monde. How dependent is France on Niger's uranium? Published 4 August 2023. Available at: https://www.lemonde.fr/en/les-decodeurs/article/2023/08/04/how-dependent-is-france-on-niger-s-uranium_6080772_8.html

France is also the largest agricultural producer in the EU. This photo shows the lavender fields in Provence, near ITER. Picture: Lauri Heroja.

In Nuclear We Trust

Bugey Nuclear Power Plant

Our journey proceeded to the flat French countryside after mountainous Switzerland. Our destination was a nuclear power plant (NPP) in Bugey. Our place of stay was in Ambierie-en-Bugey, a town with a population of 14,000 people, surrounded by vast farmland and next to a French Air Force base. Nevertheless, it was fun to be further away from cities at least for a brief while.

France is the promised land for nuclear power enthusiasts. 64 percent of the country's electricity generation comes from nuclear power, with 56 operable reactors across 18 sites, providing a capacity of 61,370 MWe. [1.]. The French energy palette consists practically of nuclear power with an ever increasing portion of renewables.

Bugey NPP, like all the other NPPs in France, is operated by the state-owned company Électricité de France (EDF). In 2023, EDF produced 69 percent of the electricity in France. The company was formed after World War II as France needed to rebuild its energy infrastructure. France and EDF emerged as a global nuclear powerhouse after the oil crisis, when France made a governmental plan to produce the country's electricity with nuclear power. The Bugey power plant is one of 13 plants constructed under the so-called Messmer Plan.

Bugey NPP has four operational reactors from Bugey 2 to Bugey 5. All of the reactors are Framatome (now Areva) type CP0 pressurized water reactors (PWR) and are the oldest reactors still in operation in France.

You don't see these kinds of cooling towers in Finland.

Bugey 2 and 3 have a capacity of 910 MW each and are cooled by water from the adjacent river Rhône. Bugey 4 and 5, with a capacity of 880 MW each, are cooled by four cooling towers. Each reactor has two 120-meter cooling towers because, in the construction phase, EDF didn't yet have the capability to build towers tall enough (170 meters) to properly cool the reactors. The site also hosts a decommissioned gas-cooled graphite moderated reactor, Bugey 1, and the site has been selected to host two new EPR2-type reactors [1.].

The plant layout is similar to other French NPPs built in the 70s and 80s: two reactors share a joint control room and turbine hall. All control systems in Bugey are still original, analog technology controlled by operators in the control rooms. Each control room employs 15 people per shift per two reactors but the whole site employs a significant 1,200 people, most of whom work in the site's offices.

Plant has strong outer security and also nuclear security standards. Each reactor pair had originally two backup generators placed on the ground but after the accident in Fukushima, third generators were installed 30 meters above ground if a severe flooding happened in the middle of the continent. Nuclear safety has also been the reason for the delays in decommissioning the Bugey 1 reactor as the project has already taken 30 years, which reminds us Finns of a particular nuclear related project back at home.

Bugey's current reactors will be running for some time as the French nuclear authority extended the operational lifetime of 32 of their oldest reactors to 50 years, meaning Bugey's oldest reactors will be running into the late 2030s. Hopefully, the investment decision will be made, and new EPR2 reactors in Bugey will keep the site operational well into the next century.

Otto Huttunen

[1] World Nuclear Association, Nuclear power in France
Available: https://world-nuclear.org/information-library/country-profiles/countries-a-f/france

"In 2023, EDF produced 69 percent of the electricity in France

With over 1,000 people working at the power plant, it took some effort to find our car again.

EATON

Powering Business Worldwide

Fimpec

Fimpec offers exciting opportunities for young professionals - Get to know our CCUS expert, Eelis

What's your background?

I began my studies in chemical engineering at Aalto University's in the fall of 2016. During my bachelor's degree I studied materials science as my major, and in my master's, I majored in industrial energy processes.

What do you do at Fimpec?

Currently, I act as a project engineer and my work revolves around energy, hydrogen and power-to-X. Fimpec has offered a lot of room for professional growth as I have also contributed to sales, scheduled large projects and even attended to a podcast with the Minister of Climate and the Environment to discuss about future of CCUS in Finland.

How did you find Fimpec?

I approached Fimpec on a friend's recommendation, as I found their engineering services for clean transition exciting. I started at Fimpec at the beginning of 2023 as a master's thesis worker, and I did my thesis about carbon capture as a part of a larger research project.

What is the best part of your work?

The best part of my work is the process of designing something new. We are often given only a site location and preferred production capacity at the beginning of these projects, and everything else is up to design and optimization.

Any advice for students?

Don't worry about knowing everything when entering work life. As long as you are proactive, motivated and eager to learn, you'll grow into the position you want to be in. Also, don't be afraid to bring out your views, but remember to also actively listen and learn from your more experienced colleagues. At the end of the day, a well-functioning project group is what brings both great results and personal fulfillment! When applying for jobs, don't focus too much on your hard skills, but instead let your uniqueness and personality show throughout the application process. Good luck to all of you future experts!

Who?

- **Name:** Eelis Lähdemäki
- **Title:** Project Engineer
- **Education:** M.Sc. (Chem. Eng.), Industrial Energy Processes, Aalto University
- **Graduated:** 2023
- **Age:** 28
- **Hobbies:** Gym, jogging & cross-country skiing

Exploring the *Future* of *Fusion*

ITER

The last excursion of our trip was ahead, so everyone was excited. The day began with boarding the excursion bus, which took us from Marseille to ITER. When we arrived, we were greeted by a group of employees, one of whom was Finnish. The visit began with a presentation about ITER, where we learned key details about the project. The presentation covered not only the technical solutions behind ITER but also the project's timeline, milestones, and the challenges it has faced.

The development of ITER started in 1985 during a summit between the United States and the Soviet Union. At this meeting, the U.S. President and the Soviet General Secretary proposed the idea of forming an international partnership to explore nuclear fusion as a new, clean energy source. This vision evolved into ITER, which today is a global collaboration involving 35 nations, each responsible for different components of the reactor.

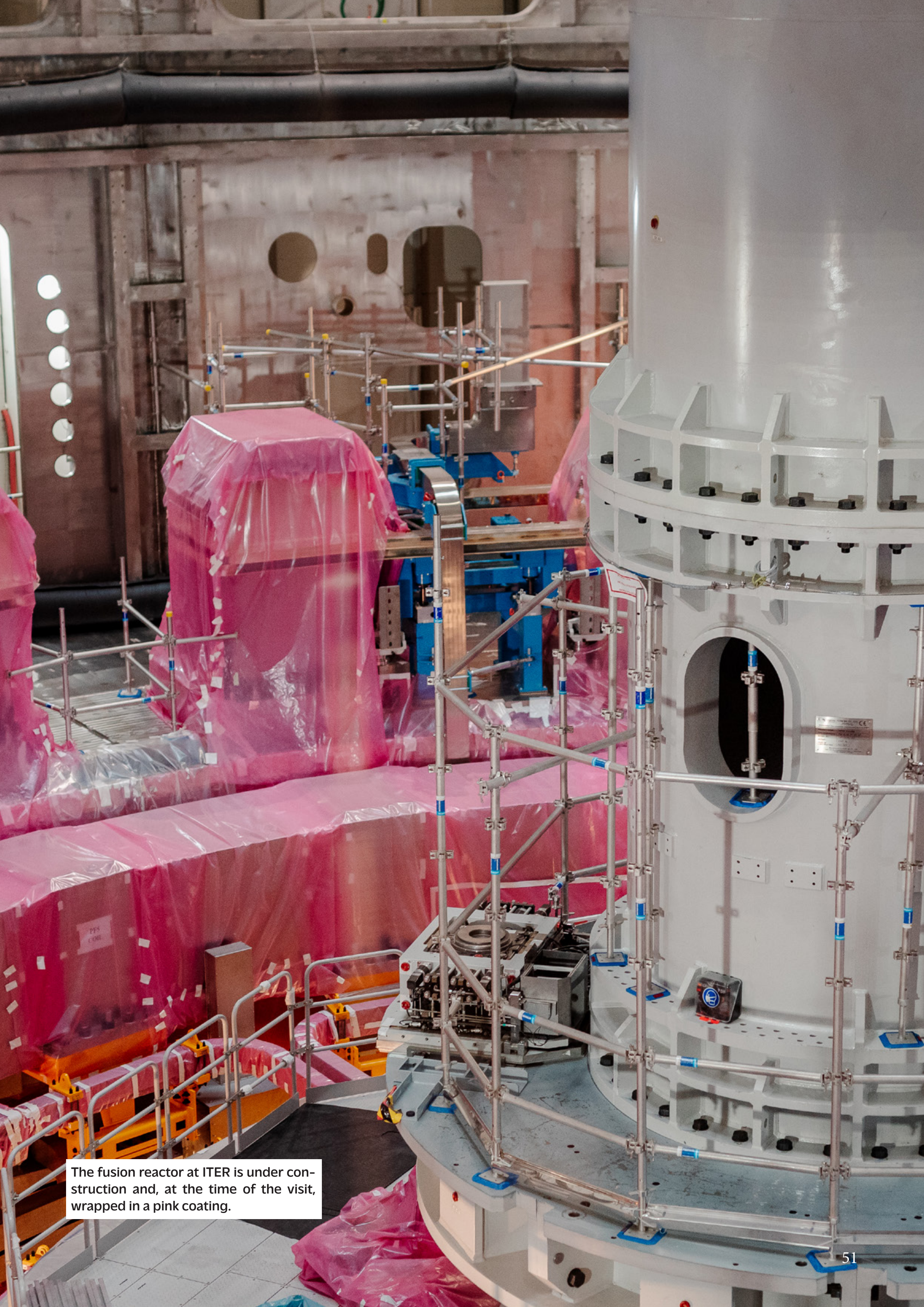
ITER is a nuclear fusion research and engineering project aimed at demonstrating the feasibility of nuclear fusion on a large scale. It uses a tokamak, a doughnut-shaped device designed to control hot plasma with powerful magnetic fields. ITER has faced challenges due to the complexity of the fusion process and the scale of the project. To sustain nuclear fusion, the plasma inside the tokamak must reach temperatures of over 150 million °C. Plasma is an extremely difficult state of matter to control, and maintaining its stability is crucial for successful fusion.

Managing work in different countries and ensuring the timely delivery of critical components is a complex logistical task. Political changes, economic crises, or shifts in priorities in any of the partner countries can further complicate progress. We learned that ITER's energy consumption is considerable due to its nuclear fusion experiments. Electricity requirements for the ITER plant and facilities will range from 110 MW to up to 620 MW for peak periods of 30 seconds during plasma operation.

ITER from the outside.

After the presentation, we were given the opportunity to tour the facility. The bus drove us around the various buildings of the ITER site. We learned that the site was first established in 2007, with construction officially starting in 2008–2009. Even though the facility was still under construction, we were able to see a surprising amount of the site's most important structures. For example, we saw the huge magnets installed in the reactor and the cylindrical structure designed to house the reactor itself. Each of us was impressed by how much we got to see during the visit.

Before the excursion, participants were asked when they believed ITER would achieve its primary objective - producing ten times more energy than it consumes. Opinions were mixed: four participants believed the milestone would be reached by 2040, three anticipated it by 2045, and six expected it around 2050. However,



The fusion reactor at ITER is under construction and, at the time of the visit, wrapped in a pink coating.

one participant was skeptical and doubted that ITER would ever reach its goal. After the excursion, the same question was asked again, and the responses had shifted. Almost all the participants now believed that ITER would not meet its goal until 2050. The lone skeptic still expressed doubt that it would ever happen.

It remains to be seen when fusion energy will be available and used on a large scale. Perhaps Lämpövoimekerho's abroad excursion in the coming decades will witness ITER in operation. Such a moment would mark a significant milestone – not just for ITER but for the future of the energy sector.

Liisa Ryhänen

> **To sustain nuclear fusion, the plasma inside the tokamak must reach temperatures of over 150 million °C**

Plastic coatings inside the tokamak reactor. →

The excursionists visiting the massive construction site. ↓

Sun, Sea, and Splendor: The Relaxing Finale on the French Riviera

Picture: Lauri Heroja

Oh, the French Riviera. A place known for its exquisite atmosphere, endless sunshine, turquoise waters and laid-back approach to life.

After centuries of conflict and change of power, the impoverished region started gaining popularity among the British upper class in the 18th and 19th centuries. The coast became a fashionable health resort for the British aristocrats, promoted as an area with health benefits due to its warm winter climate.

Perhaps you wouldn't call us jetsetters, but that doesn't make the Riviera any less of a perfect place for us to end our energetic two-week trip. Starting from northern Germany, Nice is the natural finish line for a cross-European excursion like this.
Our accommodation responsible had chosen the best hotel for the trip to be in Nice, for which the whole group was very thankful. Actual air conditioning and spacious rooms gave us Finns a sense of security and made us finally loosen up for the relaxed weekend holiday after spending the previous week in scorching 30-degree weather.

What would a mini holiday in Nice be without swimming in the Mediterranean? That's right, we hopped on a RIB, skippered by a funny Frenchman who really wanted us to enjoy the trip (and for his company to gain more market share in the highly competitive will-take-you-snorkelling-for-money industry). Soon we were flying across the water as the wonderful scenery of the city's coastline reeled past.

Seeing a coastal city from the sea is an experience in itself, but the fact that we got to go swimming in the warm and clear waters off the western side of Saint-Jean-Cap-Ferrat, was just awesome. I had carried my action camera in my backpack through the whole trip just for this moment, and it was totally worth it.

In the mid-18th century, the Prince of

Monaco signed an agreement with a French businessman, for the construction of a new casino and resort after the prince's own initiatives to build a casino had failed. The Casino de Monte-Carlo was born.

At this time, the Riviera became a popular destination for European royalty as well. When the railway reached Monte Carlo in 1870, the

population of Monaco doubled.

If you didn't already guess, we did of course visit Monaco. This tax haven of a microstate is a scene worth experiencing, although there isn't really anything surprising to see. Significant, even indiscriminate wealth is what defines these two square kilometres. Monaco is, in fact, the most densely populated state in the world and has the third highest GDP per capita. Having such little space to fit everyone, the state is full of relatively tall apartment buildings and is now expanding into the sea to build more.

Walking along the legendary Circuit de Monaco, you can sense the excitement and atmosphere the Formula One circus brings to this small city every year since the original race in 1929. During our visit, there were no Formula One cars in sight, but instead, just normal cars driving nicely within the speed limits. Normal in this case means Ferrari, Rolls Royce, Lamborghini and the occasional Mercedes, instead of the Toyotas and Volvos we are used to in Finland.

From chilling on the beach after the last dinner together to marvelling at the 100-metre yachts in Monaco, the French Riviera gave us everything we'd hoped for and sealed our amazing journey through Europe in the most relaxing and fulfilling way.

Now all that was left was to board the plane with the familiar logo and say goodbye to Nice and each other. Fortunately, we'll be left with lots of photos and vivid memories of everything we got to experience together on this once-in-a-lifetime adventure.

Iiro Mikola

Picture: Iiro Mikola

We want to thank all of our sponsors for making our excursion possible

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We also raised funding by helping organize FinNuclear's Nordic Nuclear Forum 2024, participating in YIT's Good deed campaign, as well as doing logging and forestry work.

We are grateful for all the support and funding that made our excursion possible. It is delightful to see that the industry support for students remains strong, even in challenging times!

Picture: Lauri Heroja

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