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INF'OSE

Trip to Finland

Special Edition

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OSE

OPTIMISATION DES SYSTÈMES ÉNERGÉTIQUES

CMA

Centre de Mathématiques Appliquées

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A WORD FROM THE EDITORS

Dear readers,

Last month's events have shattered the global geopolitical and energetic context. We hope this edition of Inf'OSE will give you some fresh air, as we bring you the opportunity to hop in on a tour of Finland with the students of the Advanced Master Degree in Energy System Optimisation of Mines Paris - PSL (MS OSE).

Every year, the MS OSE students go abroad for a week to discover the energy context of a new country. The purpose of this trip is to get a new point of view on the student's chosen topic. As the students this year are focusing on the impact of digital technologies on the energy transition, they naturally headed to Finland, a country at the forefront of digital development. From March 5th to 13th 2022, the many exchanges, experiences and cultural discoveries provided the OSE students with a new vision of these issues.

The students first discovered Finland's cultural and energetic context with presentations from Business France and Business Finland. They then had the opportunity to present their work and to discuss with researchers from the Finnish technical research center VTT. They also visited industrial installations from the local TSO Fingrind, the headquarters of Nokia, and a data center owned by Telia. The visits also included a view on Finnish renewable energies development, with a presentation and an exchange with Neoen, and the visit of wind turbine installations on Åland island with Flexens.

The OSE students and the Inf'OSE team wish you a wonderful trip in Finland!

Inf'Ose Team

Finnish history and society

Reading time: 2min

In order to deeply understand Finnish development context and issues, it is mandatory to take a glimpse at the organization of its society and its multicultural history, at the crossroads between Russian and Swedish Empires during its early ages, followed by the strong Soviet influence during the last century, to the Westernized lifestyle we know today.

Finnish history

Finnish lands were sparsely occupied until Russian and Swedish Empires claimed the territory in the middle of the XIIth century. Sweden finally took possession of most of Finnish lands in 1323, before expanding to the whole territory during the XVIIth century. During the Swedish era, Finland was not yet a national entity, and was governed from Stockholm. Due to this common history with Sweden, Swedish is today considered as the national language as well as Finnish.

At the beginning of the XVIIIth century, Sweden lost its status of great power and Russian pressure intensified on Finland, ending by the war of 1808-1809 and its conquest by Russia. Finland was then declared an autonomous Grand Duchy in the Russian Empire, and Helsinki became its capital in 1812. Finnish nationalist movement grew during the whole Russian era. Despite Russification attempts and independantism repression, Finland claimed its independence on the 6th of december 1917, taking advantage of the Russian Revolution. The Finnish Republic was declared on the 17th of July 1919, and saw a strong growth during the 1920s.

In 1939, Finland was defeated by Russia during the “Winter War” and was forced to cede a part of its land. Without taking part in the pact linking Germany, Italy and Japan, Finland then allied with the former against the USSR in 1941 during the Second World War. The country was finally constrained to transfer a new part of its territory to the Soviet Union as a result of the signature of the 1944 Armistice

Figure 01: Map of Finland

With the signature of the Agreement of Friendship, Cooperation, and Mutual Assistance in 1948, the USSR reinforced its influence on Finnish political life. The country is then constrained to apply a strict neutrality rule during the whole Cold War, despite its westernizing lifestyle. This proximity with both sides lead Finland to act as mediator between Eastern and Western Blocs. The Helsinki Accords, promoting the "détente" between East and West, were signed in 1975.

After the collapse of the USSR, the 1948 treaty ended and new accords were drafted with Russia. Finland assumed its westernized way of life, and joined the European Union in 1995.

Social context

Finland counts 5,5 millions inhabitants with a GDP of 268 B$ in 2020, ranking 13th by GDP per capita with 48 786$/cap.

Finland is focused on a welfare state and egalitarian model, with reduced class differences. Within organizations, hierarchical relationships are tenuous and rather horizontal. The free education system is known for its soft and effective pedagogy. With free health-care, high unemployment benefits, and decent social housing, Finnish system takes care of its population as a whole. Paying high taxes is well accepted seeing all the advantages that it brings. The Finns are globally confident with their politics and police forces. The country also strongly supports gender equality.

A social organization which seems to bear fruits: Finland is declared happiest country in the world for the 4th year in a row, according to the UN World Happiness Report.

The country claims a leading position regarding ecological issues and hopes to achieve carbon neutrality in 2035. In order to reach this goal, the country wants to rely on technological and digital development.

The Finnish energy mix

Reading time: 2min

The Finnish energy mix has several striking characteristics. Firstly, Finland has a high reliance on biofuels and biomass, due to its wood industry. Many by-products are used in the production of electricity, heat and for transportation. Secondly, the country makes extensive use of heat networks, both urban and industrial. Finally, Finland is one of the few countries in the world whose main source of electricity production is nuclear power.

It should also be noted that Finland has a well-diversified energy mix with numerous production sources. However, while some are local (notably biomass, representing about 30% of total consumption), many are imported. In particular, Finland imports all its natural gas and the vast majority of its oil, coal and nuclear fuel from Russia. A very large part of its electricity (about 20% of its consumption) is also imported, historically mainly from Russia, with a shift more recently to imports from Sweden.

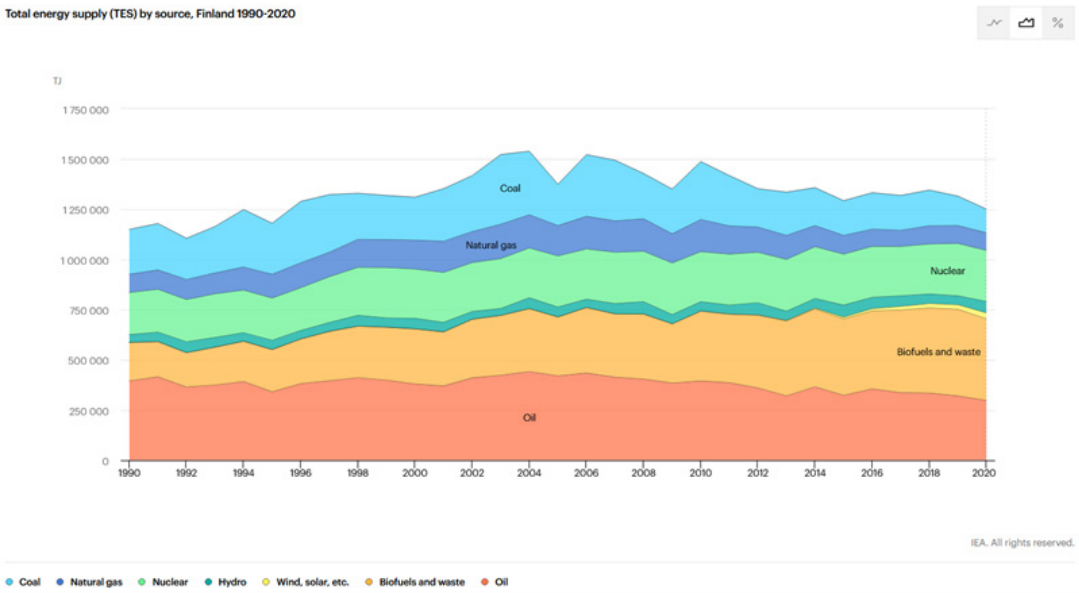

Figure 01 : Finnish energy mix 1990-2020 (source : AIE)

THE FINNISH ENERGY MIX

In the last 10 years, the share of imported electricity has increased in the Finnish electricity mix, as has wind power. On the other hand, the share of fossil fuels (historically gas and coal) has decreased.

Heat networks tend to remain stable, although urban networks have been competing with heat pumps in recent years. Historically, urban networks used mostly coal-fired cogeneration plants but today wood-fired cogeneration plants are replacing them. Industrial heat networks use biomass for the most part. It is mainly by-products of the paper industry ("black liquor") that are burned.

Finally, it is not possible to talk about the Finnish mix without mentioning Olkiluoto 3. This should have been the first EPR in operation in the world. Construction work began in 2005, with delivery scheduled for 2009. On December 21, 2021, the reactor finally started up. It will be in full production in June 2022. It will produce about 15% of the country's electricity.

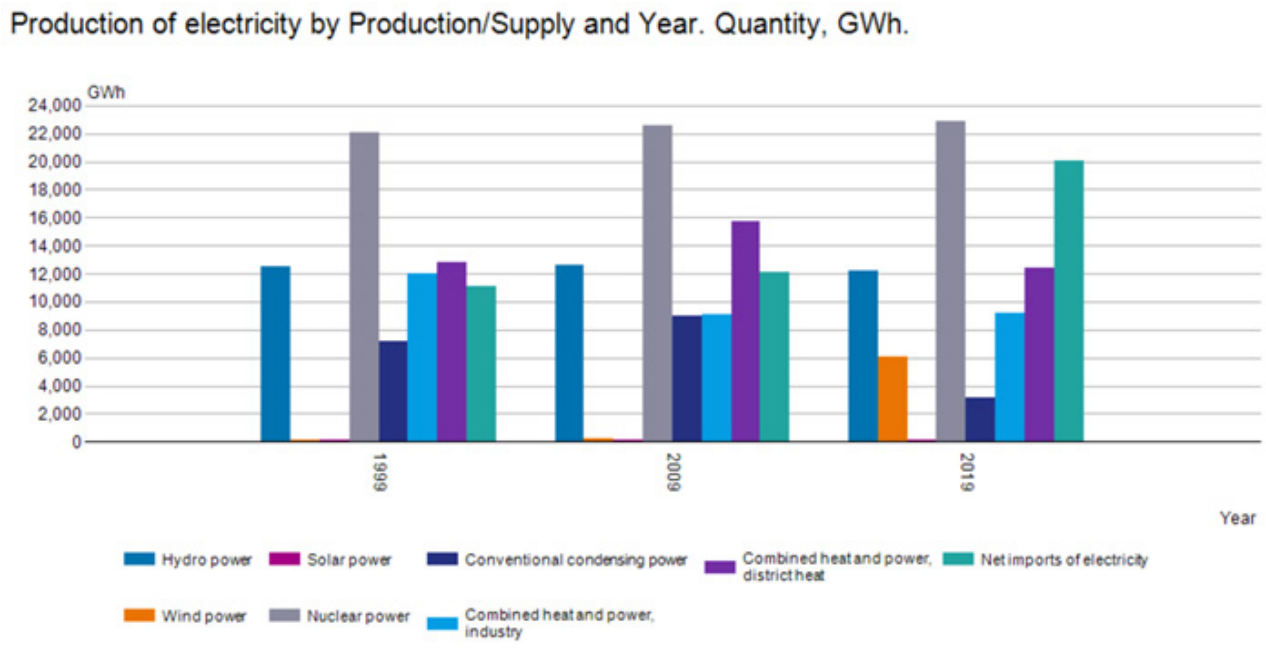

Figure 02 : Production of electricity by Production/Supply and Year, Quantity (source : Statistics Finland)

Business France

Reading time: 2min

On Monday, March 7, we were warmly welcomed at the French Institute of Helsinki by its director Stéphane Schorderet, as well as by Sonia Couprie, Outi Alapekkala, Patricia Pouliquen and Vincent Joly, all economic, scientific or higher education Attachés at the French Embassy of Finland. Located in the city center in the heart of the Kamppi district, the French Institute offers to the Finnish public a media library and a language center where classes are taught by French teachers. The Institute's mission is to promote exchanges between France and Finland in the main areas of cooperation. Regarding education, the Institute supports the only French school in Finland, which follows the French curriculum until the fifth grade, promotes French universities, and intensifies scientific exchanges between French and Finnish researchers. Regarding culture, the Institute promotes Franco-Finnish exchanges by bringing French artists to Finland and vice versa. The energy situation in Finland has also been presented this morning. Finnish electricity production is mainly nuclear (28%) and renewable (40%), especially wind, hydro and bioenergy. In response to climate change, Finland has set a target of net zero emission by 2035. To reach this very ambitious target, the country is counting on an expansion of its onshore wind farms through strong investments by 2030. Wind power has already grown exponentially in recent years with production amounting to 1 TWh in 2014 and nearly 8 TWh in 2020.

French companies Neoen and Valorem are well positioned on the Finnish wind market. Biogas and solar energy, to a lesser extent, will complete the 2035

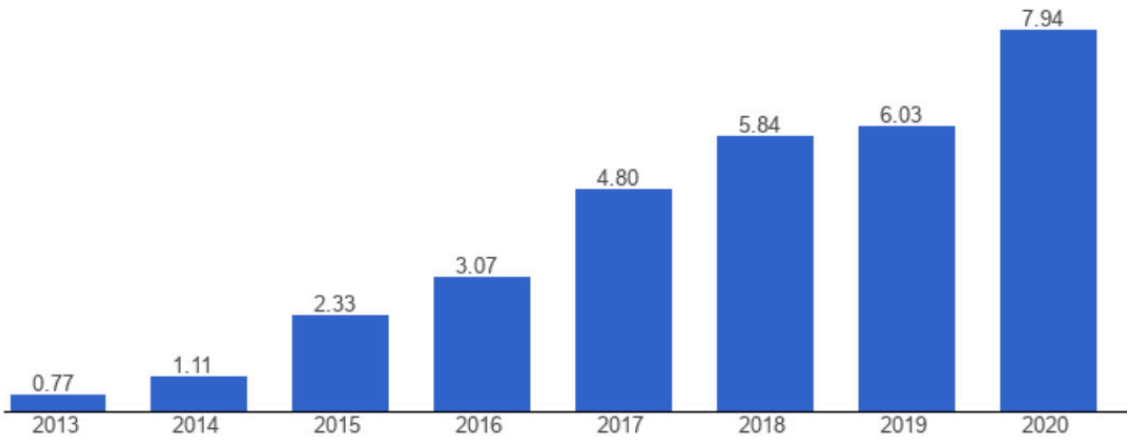

Figure 01 : Wind power production in Finland from 2013 to 2020 (TWh)

roadmap. In addition, Finland has two nuclear reactors, and the construction of a third, commercialized by Areva, began in 2004. However, the project has encountered problems like those encountered in the construction of Flamanville in France, and has just been commissioned after a delay of 12 years.

The third presentation outlined Finland's economic situation. This country of 5 million inhabitants, with one fifth of the population living in Helsinki, has an important paper and metal industry. Exports represent 40% of GDP, making it a very open economy. Despite its historical industries, Finland is innovative, with an economy that is increasingly focused on high-tech activities with many multinational companies. Nokia for telephony, Kone for elevators, and Supercell and Rovio for video games must be quoted. Technology has penetrated very deeply into the country and at all ages. For instance, mobile phones are mandatory for pupils from elementary school because they are used for teaching.

The fourth and final presentation focused on Finland's energy and climate strategies for 2030. The major points are as follows: abandon coal and peat in the energy mix, increase wind production, a minimum of 10% biogas in gas consumption, accelerate the development of electric cars, develop forest biomass, and decrease oil imports.

These presentations allowed us to get acquainted with the Finnish energy context, which has proven very useful for the other visits during the week. For this, we warmly thank each of the speakers and the whole Business France team for their welcome.

Business Finland

Reading time: 30sec

On Tuesday, March 8, we received a visit from Sari Toivonen, Senior Advisor at Business Finland. Business Finland is a government agency under the Ministry of Economic Affairs and Employment of Finland. Its objective is to promote the competitiveness of Finnish industry by providing financial services and internationalization support to companies. Business Finland employs about 680 experts and has nearly 40 offices worldwide.

The companies funded by Business Finland since 2020 include Nokia, Kone and Neste, which are respectively aiming at making Finland a 5G pioneer, developing mobility solutions, and reducing the use of crude oil.

In exchange for the funding, the companies commit to increase their R&D activities in Finland by several hundred million euros, and to create hundreds of new jobs by 2024.

Figure 01 : Sari Toivonen presenting Business Finland startegy to Master OSE students

VTT: The Technical Research Center of Finland

Reading time: 2min

The Technical Research Center of Finland (VTT) is a research organization that focuses on developing technologies and on climate change mitigation. Their objective is to address issues by developing carbon-neutral technologies as well as sustainable products and materials. The research unit that hosted us is specialized in "demand response" and smart systems.

Their presentation was focused on smart energy systems. An energy system is composed of the production, distribution and consumption of energy at the scale of a building, a city, a country or even a continent. These three components are evolving rapidly due to the introduction of new technologies and the growing number of interconnections between different forms of energy such as electricity, heating, cooling and fuels. Finding opportunities and synergies to combine them is the backbone of the future energy system.

This is what the "Smart Otaniemi" project is all about. With this project, VTT experiments in their own offices by collecting in real time data such as energy consumption, occupancy, temperature preferences or people flows. At the same time, they are developing algorithms and are experimenting ways to link energy use in buildings to future commercial applications. "Smart Otaniemi" is also a testing ground for community-based energy sharing. For example, an energy community could be composed of an apartment building with solar panels on the roof, energy storage batteries in the basement and a few shared electric vehicles. The goal is then to optimize the production and use of energy at the community level in order to better exploit it at all levels.

Figure 01 : Smart Energy System - VTT

After the presentation given by VTT, it was then the turn of the OSE students to present the fruit of their work via two presentations attended by around fifteen VTT researchers. The first presentation addressed the topic of "demand response" as a potential asset for the energy transition. Although the large-scale deployment of renewable energies is commonly presented as a way to achieve carbon neutrality, the students pointed out that electricity is a very specific energy carrier as it cannot be stored. Therefore, replacing carbon-intensive power plants with intermittent sources, such as solar and wind power, challenges the control and safety of the grid. So, how to ensure the control and flexibility of such systems? The students tried to answer this question by presenting various case studies using the latest digital technologies able to adjust demand with production, such as the Equigy platform, created by various European energy distribution network managers and using blockchain technology to better balance networks, or the "Your Energy Moment" pilot project in the Netherlands, where participants can program the operation of their household appliances according to the price of electricity using smart meters.

The second presentation focused on digital technologies as a double-edged weapon for the energy transition. On the one hand, as the first presentation showed, digital technologies are one of the greatest forces for transforming the energy sector. On the other hand, this digitization of all uses will have several negative consequences on the energy sector. Firstly, the energy consumption induced by digital technologies is growing steadily and is expected to increase by 50% in the next 10 years, from 80 TWh in 2018 to 120 TWh in 2030. Secondly, a highly technological energy system can be exposed to cyber attacks that can lead to its interruption or a data leakage. Finally, the deployment of digital technologies is leading to an explosion in the use of certain rare metals, which in turn can lead to shortages and geopolitical tensions. Thus, caution should be exercised with the digitization of the energy sector, as the balance between the benefits and the risks is still uncertain.

These presentations gave rise to very interesting exchanges between students and researchers. We would like to thank Edgar Bohner, vice-president, Kari Mäki and Petra Raussi, researchers, for their welcome and interest.

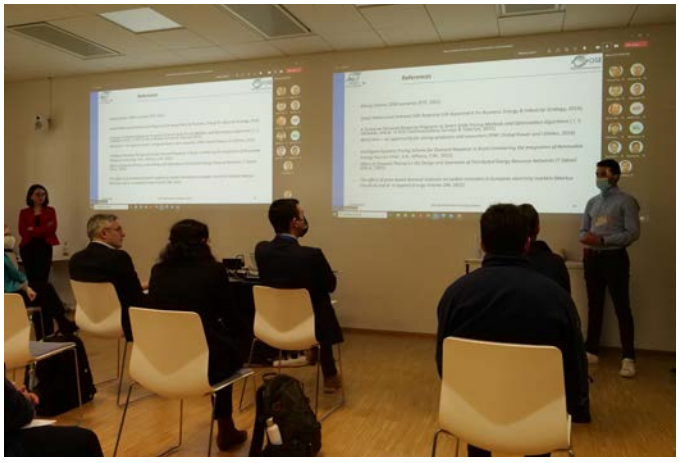

Figure 02 : OSE students presentintg in front of VTT researchers

Fingrid

Reading time: 2min

The OSE students visited the premises of Fingrid, which is Finland's national electricity transmission system operator. Fingrid manages 13,700 km of power lines, 91 transformers, 115 substations and 450 employees.

Finland is one of the most advanced smart grid markets in the world, with over 3.7 million smart meters. To support this momentum, Fingrid is looking to develop solutions for its smart grid 2.0 such as IoT, 5G, artificial intelligence and blockchain. These enable energy efficiency monitoring, electric vehicle charging, demand-side energy management, distributed energy production and improve the customer experience by providing greater visibility. French players operating in Finland in this field include Legrand, Schneider, Rexel and Sonepar.

Before leaving to visit one of their substations, Fingrid shared with us their vision of the Finnish power grid. It is important to note that, by 2050, the overall energy demand of the European Union should decrease by ⅓, while energy imports should be reduced by 90%. Solar and wind energy should account for 75% of the EU's total electricity production, compared to 20% in 2020. All of these changes will have huge implications for electricity networks due to the evolution of the technologies used and the geographical dispersion of all these electricity generators. Fingrid estimates that the development of the network will require an investment of 3 billion euros by 2035. While this is a record figure for Finland, it is moderate compared to many other European countries.

In the second part of the tour, we visited the Länsisalmi power substation. This substation, built in 1994, has a capacity of 800 MW and supplies electricity to two of Finland's largest cities: Helsinki and Vantaa. It is equipped with 400 kV transmission lines which are connected to other substations in the country, two 400/110 kV transformers and two 110 kV transmission lines connected to two other substations, which in turn supply electricity to the 800,000 residents of the region. The station is fully automated and is monitored from the Fingrid control center.

We warmly thank the Fingrid team for the presentations and the visit which allowed us to better understand how electricity is transmitted in Finland.

Figure 01 : OSE students at Länsisalmi power substation

Nathan GUILBAUD

Neoen

Reading time: 2min

On Wednesday 9th March 2022, we have been invited to a presentation of Neoen.

Founded in 2008, Neoen is the leading French independent producer of renewable energy and a major player on the world stage. After building their first solar park in France, the company has expanded to Portugal and Australia, with the construction of the largest batteries in the world, as well as Mexico and Finland.

As a pure player in renewable energies, Neoen is developing a complete technological mix (solar, wind and storage). In each of these segments, they have a cutting-edge expertise enabling them to manage large-scale projects from start to finish.

As an integrated player, present at all stages of the life cycle, they develop their own projects and maintain their assets over the very long term. Their total capacity in operation or under construction is currently of 4.8 GW and they are targeting more than 10 GW by the end of 2025. They have more total installed capacity in solar (2.6 GW) than in wind (1.58 GW) and batteries (526 MW).

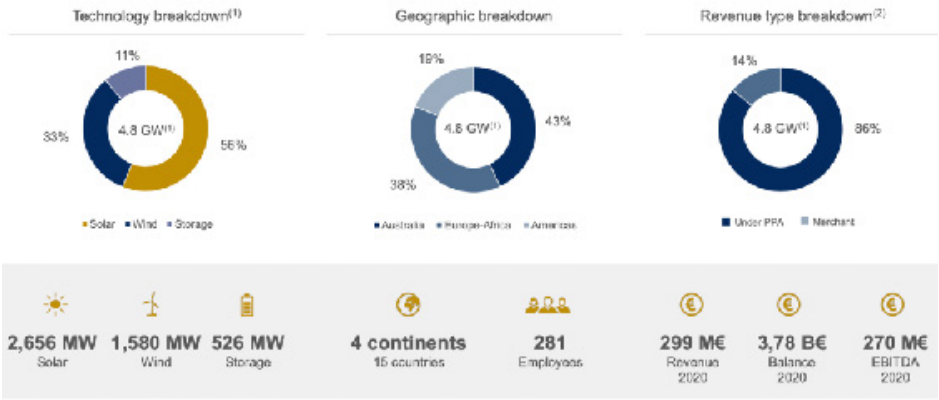

Figure 01 : Neoen key numbers

Finland's energy mix is dominated by oil, nuclear, imports, biomas, and hydropower. Imports represent 20,1% of Finland's total energy needs, more than biomass (15%) and hydropower (18%). Coal will be banned after 2029. To replace fossil energy and coal, Neoen focuses on onshore wind deployment because land is owned by the municipalities, which keeps them from having to deal with social acceptability and the "not in my backyard" discourse of citizens.

The company will claim possession of 2000 turbines in 3 years, with 692 actually in construction. Their average hub height was around 30m in 1993 compared to 150m in 2021. 60% from

the total wind power energy expected is sold by PPA and the other 40% on the market. 90% of wind farms are on the west coast. For military reasons, building wind turbines near the Russian border is hazardous, as it would interfere with radars.

The company finances most of their projects through a combination of equity capital and long-term loans. As project owner, they are closely involved in supervising the construction of our power plants.

Listed on Euronext Paris since October 2018, Neoen confirmed its dynamic growth and operating performance in 2021.

The Neoen's ownership structure is dominated by Impala, which is a long-term investor that supports growth projects in Energy, industry, Cosmetic, etc. The FSP is registered with the French Financial Markets Authority (AMF) and seeks to promote long-term equity investments by taking strategic stakes in French companies. Bpifrance, the French national investment bank, is particularly committed to renewable energy, and invested some €2.2 million to finance the energy transition.

We would like to thank Jerry, Kiira and Neoen very much for their welcome and their presentation which gave us insight into the development of onshore wind farms in Finland.

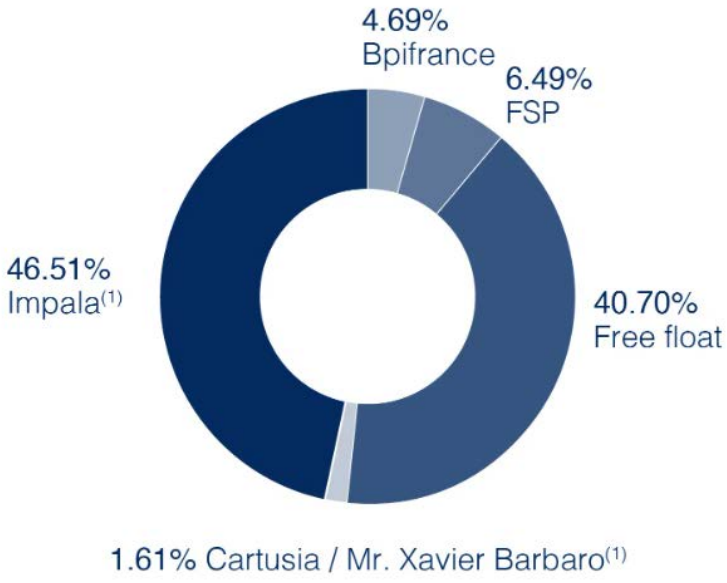

Figure 02 : Ownership structure of Neoen

Nokia

Reading time: 1min

On the morning of Wednesday, March 9th, we were received at Nokia's headquarters in Espoo by Olli Salmela, director of Nokia Bell Labs, Anu Välimaki and Sami Sarpola. Founded in 1865, Nokia was the world's leading mobile phone manufacturer from 1998 to 2011. In 2014, this Finnish telecom giant made a strategic shift by handing over its mobile terminal division to Microsoft to focus on broadband network solutions. In particular, the company has signed a contract for the development of 5G infrastructure with 66 telecoms operators worldwide, including three of the four main US operators. In France, Nokia is in partnership with Free and Orange.

From the Nokia Bell Labs showroom, Nokia employees presented one of their latest innovations: a liquid-cooled 5G base station to reduce noise, power consumption and CO2 emissions from mobile network infrastructure. For the moment, 5G consumes more energy than 4G and much of this energy is converted into unused heat. Nokia's new liquid cooling solution, called Elisa, reduces 5G base station energy costs by 30% and CO2 emissions by 80%. Compared to traditional 5G base station cooling units, these liquid cooling units are half the size and 30% lighter. They are also silent, maintenance-free and have a 4000 times higher heat transfer capacity.

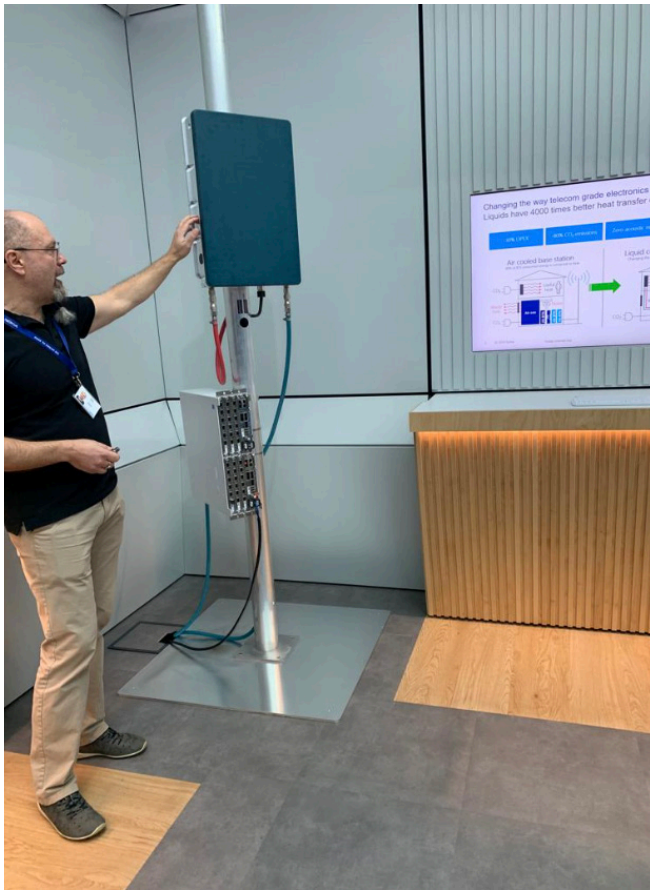

Figure 01 : Demonstration of the liquid cooling unit

The demonstration of Nokia's innovation capacities continued with the presentation of a new solution called "Intelligent RAN Operations", designed to manage the increasing complexity of 5G networks. This solution implements Machine Learning algorithms to automate common network management tasks with a greater ability to detect, categorize and resolve issues in real time. It saves time and efficiency while reducing human error. This innovation also includes intelligent energy saving features by anticipating the demand of each 5G antenna individually through Machine Learning

algorithms. This way, each 5G antenna can adapt its activity and therefore its energy consumption according to the observed traffic in the area. By allowing 5G antennas to adapt to their environment, this innovation can lead to a 15% reduction in their energy consumption.

This visit, full of technology and innovation, heralds a transition to more sustainable technologies which is already well underway in the telecom sector.

Figure 02 : OSE students at the entrance of Nokia Bell Labs

A tour of Telia's data center

Reading time: 1min

The Finnish-Swedish group Telia, a well known telecommunication company, was kind enough to receive us and let us enter their data center in Helsinki.

The datacenter, located in Pitäjänmäki, on the northern outskirts of Helsinki, is an imposing building with clean lines, perfectly harmonized with the colors of the urban neighborhood. The 23-meter-high building, with 34342 square meters spread over 4 floors, was built between May 2016 and April 2018 and required a 160 million euros investment. The warehouse, with a capacity of 5,000 racks (IT containers) and 200,000 servers, aims to be a model of energy efficiency.

Figure 01 : Data Center of Telia in Helsinki (source Telia)

Eero Lindqvist, senior manager of Telia's Data Center Business, met with us. He has been following the project since April 2009, when the idea was still in the making. The goal of this project was to respond to the needs of the company, whose existing facilities were insufficient to meet the explosion of digital consumption.

This new infrastructure is designed to meet the needs of Telia but also those of its customers (Nokia, Relex, the Finnish public health, etc.). It can adapt to different requirements of equipment (rental of a rack or a complete system), connectivity (four fiber channels connected to different national and international operators), security and standards.

Commissioned on June 5, 2018, the datacenter is currently operating at half capacity for a 24 MW maximum power and is powered through two 50 MW 110/20 kV transformers. The electrical system is further subdivided into 4 blocks, each with its own UPS (Uninterruptible Power Supply) battery and backup generator: 78L Caterpillar diesel generators capable of powering the system for 48 hours.

A forerunner in energy efficiency, the center is certified by the Certified Energy Efficient Data Center Award and the Leadership in Energy and Environmental Design. The design was explained by Joni Solakuja, production manager of the center, before taking the guided tour.

Its location is also thoughtful: located between Helsinki and Espoo, a partnership has been established with the energy producer Fortum to recycle the 258,000 MWh of annual heat generated and transport it to both cities.

B A TOUR OF TELIA'S DATA CENTER

We would like to thank Eero Lindqvist and his team for allowing us to enter Telia's data center, an example of cooperation between local authorities and private players. These initiatives allow the use of industrial waste heat, which represents a 109.5 TWh potential of unused waste energy in France [1].

Source :

[1] Les énergies de récupération : renouvelables et attractives !, Dalkia, 2022

Figure 02 : Eero Lindqvist and his team presenting Telia's Data Center to the OSE students

Flexens

Reading time: 2min

On Friday, March 11th, we went to the Åland archipelago, an autonomous Finnish province located in the middle of the Baltic Sea between mainland Finland and Sweden. This archipelago has nearly 6,500 islands of all sizes, of which only about 60 are inhabited. Unlike the rest of Finland, which is officially bilingual in Finnish and Swedish, the province has Swedish as its official language. The region has the best wind and sun conditions in the country, which makes it an excellent place to build wind turbines.

We visited the Nuhamn archipelago, which has 6 wind turbines. They were built in 2007 and have a maximum production capacity of 2.3 MW each. Their height is 64 meters while the rotor diameter is 71 meters. The six wind turbines produce approximately 17% of Åland's total electricity consumption. In 2008, the total production was 43.5 GWh. The students had the opportunity to go inside one of them and observe a complete shutdown.

In the afternoon, we joined the Flexens offices in Mariehamn, where CEO Berndt Schalin exposed his company's vision. According to Flexens, as the availability of bioenergy is limited and geothermal energy is expensive, wind and solar should account for 70-90% of primary energy in a 100% renewable system in the future. However, these intermittent energies create major challenges such as price volatility and grid stability. In this context, Flexens proposes sector coupling, the integration of storage solutions and the implementation of emerging but not yet commercially viable technologies. In the future, batteries alone will not be sufficient to store energy from intermittent sources. To develop large-scale storage capacity, emerging technologies such as green hydrogen, power-to-X and heat storage must be used.

Figure 01 : The students at the foot of the wind turbine of Flexens

Their Smart Energy Aland project is a test bed for a 15,000 person company, demonstrating how a company can run self-sufficiently on renewable energy without increasing the cost to the end customer. The project, based on several scientific studies, was launched in 2014 as a public-private partnership.

We thank Jim Haggblom and Berndt Schalin for

opening the doors of their company to us. This rich day was an unique opportunity for the OSE students to learn more about wind energy.

Figure 02 : The students inside the wind turbine

OSE CONFRENCE 2022

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22nd edition of OSE Confrence

THURSDAY SEPTEMBER 29TH 2022