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S&P Global
Commodity Insights

Nucleonics Week

Volume 64 / Issue 28 / July 12, 2023

Spanish election could open the door to nuclear life extensions

- Reactor closure plan agreed to in 2019
- Regulator to start work for Almaraz closure in 2024

The permanent closure plan for Spain's seven operating reactors has become a key difference between Spain's two main political parties as the country goes to the polls July 23.

While the leading opposition party has staked out a position of reversing the nuclear closure plan, the current government has stood by a pact agreed in 2019 with the two principal plant operators for a sequential closure of all nuclear units, with a combined capacity of just under 7.4 GW, between 2027 and 2035.

The largest opposition party and current leader in the opinion polls, The People's Party, said in its manifesto July 4 that it supports "an ordered and just energy transition" that includes reversing the reactor closure plan and extending the lifespan of existing units.

This would be carried out in conjunction with the nuclear safety body, Consejo de Seguridad Nuclear, it said, without adding more precise details.

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Norwegian company sees potential for SMRs as country debates nuclear energy

- Current government in Norway opposes nuclear energy use
- Legal, political change would be needed for reactors
- Advocates see role for small reactors, nuclear energy research

The startup company Norsk Kjernekraft hopes to have commercial small modular reactors operating in Norway in 10 to 15 years, company CEO Jonny Hesthammer said in an interview July 6, as debate over potential use of nuclear power in Norway heats up.

Earlier this year, the Labor-led Norwegian government gave a firm no to commercial nuclear power. But groups within the Labor party favor building reactors as do other political parties.

Hesthammer said Norway could draw on its experience in developing its oil and gas industry, now the key to the country's economy, to develop a nuclear power industry.

"We have built up an oil and gas industry from scratch," he said. "We are very good at ensuring it is safe."

Norsk Kjernekraft's two main owners are wealthy Norwegian

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Pakistan, China agree to build new Hualong One nuclear reactor at Chasma plant

- Pakistan has six operating reactors
- Country plans to have 8,800 MW capacity by 2030

Pakistan's Atomic Energy Commission and China National Nuclear Corp. signed a memorandum of understanding June 20 for the construction of a new 1,200-MW Hualong One reactor, Chasma-5, at the Chasma nuclear plant, the country's Prime Minister Shehbaz Sharif said on Twitter that day.

The signing of the agreement "is a major step forward towards the construction of the project that will add 1,200 MW clean, affordable & reliable nuclear power to the [Pakistani energy] system," Sharif said in his tweet.

Pakistan has six operating reactors with a combined capacity of 3,530 MW.

The Chasma nuclear plant, also known as Chasnupp, has four operating Chinese-built CNP-300 reactor with a combined capacity of 1,330 MW. These four units started operation between 2000 and 2017. The country has two operating Hualong Ones, Kanupp-2 and-3, which started operation in May 2021 and April 2022, respectively.

Chasma-5 will be developed through a Chinese investment amounting to $3.48 billion, according to the Pakistani prime minister. He did not say how long construction would take, but did say that work would begin quickly. Previous Chinese Hualong Ones in Pakistan have taken six years to build.

Under the Pakistani government's energy plan, overseen by the government's Pakistan Planning Commission, the government has initiated a strategy to increase the country's nuclear capacity to 8,800 MW by 2030, although even after Chasma-5 is completed, the country's nuclear capacity would only be 4,550 MW.

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Sharif also said on Twitter June 19 that he "Can't thank Chinese leadership enough for their continued trust in Pakistan," adding that despite inflation, the project cost of $3.48 billion first agreed between China and Pakistan in 2017 would not increase, meaning that China was absorbing additional costs of around Yuan 750 million ($104 million). Sharif said that the construction of Chasma-5 would be funded by a Chinese "investment," but did not provide any further details as to whether this would be in the form of an intergovernmetal loan, a grant or some type of construction and performance contract.

Pakistan became a nuclear power producer in 1972 when the 137-MW Kanupp-1 started operations in Karachi. The unit is a pressurized water reactor that was constructed with the assistance of Canada.

The PAEC is the only institution in Pakistan authorized to undertake nuclear power generation. Kanupp-1 was permanently shut in August 2021, but the two new Chinese reactors were subsequently added at the plant. Construction of Kanupp-2 started in 2015 and that of Kanupp-3 in 2016,

The Pakistani fiscal year runs from July 1 to June 30. In the 11 months from July 2022 to May 2023, nuclear energy in Pakistan produced around 22,197 GWh, compared with 16,982 GWh in the same period a year earlier, an increase of around 31%, according to Pakistani government data.

Nuclear power comprised about 19.2% of the country's electricity mix in the July 2022 to May 2023 period, compared to around 13.1% in the same period a year earlier, the government data said.

The Hualong One reactor, which is also known as the HPR-1000, is the main offering of China's nuclear export program. The unit is an indigenous Chinese pressurized water reactor developed jointly by state nuclear companies CNNC and China General Nuclear, incorporating a combined version of each company's design for the unit.

It has only been exported to Pakistan thus far.

Despite its success there, the Chinese reactor export program has suffered some setbacks, including in the UK, where political pressure on energy security grounds forced the abandonment by CGN of the planned construction of two Hualong Ones at the Bradwell B plant in Essex, around 30 miles east of London.

— Haris Zamir

Utilities look to boost nuclear fuel inventories after year of uncertainty

- Potential cutoff of Russian fuel spurs action
- Larger enriched U3O8 stocks seen as key
- Supply strategies vary among utilities

After more than a year of uncertainty over the potential for a cutoff in nuclear fuel imports from Russia, nuclear utilities in the US and Europe are considering changing their inventory practices, including by keeping more enriched uranium on hand, to better protect against geopolitical surprises, nuclear fuel industry officials have said.

"We need to build more resilient supply chains," said Tony Williams, a senior advisor to Swiss nuclear operator Axpo who has been involved in the company's fuel procurement function for decades.

Utilities are considering the need for different policies on

Platts
S&P Global
Commodity Insights

Nucleonics Week

ISSN: 0048-105X

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Nucleonics Week is published 51 times yearly by S&P Global Commodity Insights, a division of S&P Global, registered office: 55 Water Street, 37th Floor, New York, N.Y. 10038.

Officers of the Corporation: Richard E. Thornburgh, Non-Executive Chairman; Doug Peterson, President and Chief Executive Officer; Ewout Steenbergen, Executive Vice President, Chief Financial Officer; Steve Kemps, Executive Vice President, General Counsel

how much inventory to hold and what form to hold it in following the February 2022 invasion of Ukraine by Russia. Sanctions following the invasion have not targeted nuclear fuel directly, but a future ban on Russian enriched uranium has been discussed by lawmakers in Europe and the US and utilities are moving to diversify away from Russian nuclear fuel components.

Axpo is weighing a variety of measures it could take to increase inventory at key points of the supply chain, including having more enriched uranium product staged at multiple fuel fabricators to guard against future disruption, Williams said during a session June 6 at the World Nuclear Fuel Markets conference in Slovenia.

The impact of the geopolitically driven security of supply concerns may be a collective increase in nuclear utility inventory in the US and Europe, but the increase will vary from utility to utility and is not expected to be "dramatic," said Nima Ashkeboussi, head of nuclear fuel for the Nuclear Energy Institute, in an interview July 6. For example, regulated utilities may face existing rules at some state utility commissions that curb spending on bigger fuel inventories, he said.

"It's complicated. Holding nuclear fuel inventories is very costly on a balance sheet," Ashkeboussi noted.

Tuomas Rantala, head of the nuclear fuel unit at Finnish utility TVO, speaking at the same event June 5, said TVO may need to hold more of an EUP inventory in the future.

EUP has become a flexible solution for uncertainty in the nuclear fuel supply chain, considering it contains embedded conversion and enrichment, which are the markets dominated by Russian supply and the areas in which fears of a supply disruption are greater, Ashkeboussi said.

Entergy, which operates four nuclear plants in the central US, is reviewing its inventory policies "because markets have changed," said Karen Radosevich, senior manager of nuclear fuel supply, during the WNFM meeting. "We are reassessing how much we might want to hold in the future," she said.

She noted that the utility is under an obligation to keep fuel costs reasonable, which would factor into any decision.

While the nuclear fuel supply chain as operated by most utilities appears to be overly redundant, with good inventory and two suppliers at various stages to protect against disruption, Axpo's experience in the past year and a closer examination of the situation showed a need for improvement, Williams said.

The company, which is not bound by contract reviews conducted by the Euratom Supply Agency, had been a buyer of Russian enriched uranium, he noted.

Case studies show disruption potential

Supply chain challenges have shown that even having two suppliers cannot always mitigate all challenges, Williams said.

Axpo maintained an inventory of enriched uranium product that should have protected it from any supply disruptions, but that inventory was located at the site of one fuel fabricator, he said. A second fuel fabricator was available to the company, but a valid contract was not in place for a period of time.

Axpo had previously experienced challenges to its fuel supply when a technical issue emerged with fuel from one vendor and separate serious quality issues emerged from its other supplier, Williams said, without naming the suppliers.

At one point, an anti-nuclear non-governmental organization successfully blocked shipments of nuclear fuel from Germany, he added. Because fuel from the backup fabricator would have also had to be shipped through Germany, the potential for fuel not being delivered to its reactors was significant, but a legal challenge resolved the issue without much impact, he said.

Recommendations for more resilience

A review of its supply chain by an outside specialist found that Axpo's practices in nuclear fuel had resulted in a reliable and robust supply chain but one that lacked resilience, Williams said. The consultant recommended that Axpo sign mid- to long-term contracts with maximum flexibility on delivery timing and volume, that it have multiple fuel fabrication contracts at all times and that it maintain an inventory of enriched uranium product at each fabricator, Williams said.

In addition, the utility should increase the amount of fresh fuel on hand, synchronize the availability of fuel with commitments to generate power in the future and develop more diverse transport routes as all current routes go through Germany, he said in slides for the presentation. The company may not adopt all the recommendations, he noted.

There are costs to boosting inventories, but they are outweighed by benefits, Williams said. "I know that it ties up capital, but it mitigates some serious risks."

The importance of nuclear fuel is outsized compared to its costs, Williams added, meaning the consequences of any disruptions can levy a huge toll in lost power revenue. "We were doing a good job of managing known risks ... however, the leverage of nuclear fuel in the value chain due to its low cost relative to its ultimate output is unique," he said.

Utilities have reported ramping up spending on nuclear fuel in the past year, with some planning to continue to do so.

Large US utilities report increased spending

Duke Energy, in its annual report filed in February, said it has secured nuclear fuel components through long-term contracts covering uranium through 2024 and conversion and enrichment services through 2026. A year earlier in its 2021 annual report, Duke said it had fully covered its nuclear fleet for uranium and conversion services only through 2022 and had enrichment fully covered to at least 2023.

Duke intends to spend $1.9 billion on nuclear fuel between 2023 and 2025. That is considerably higher than the $1.2 billion in nuclear fuel Duke said in 2022 it would purchase between 2022 and 2024, the previous rolling three-year period. Ashkeboussi said those increases are more likely to reflect the increased costs of conversion and enrichment rather than increased inventories of nuclear fuel.

Constellation, the largest US nuclear operator, said in February it was increasing its spending on nuclear fuel sharply in direct response to the Russian invasion of Ukraine and potential disruption of the market.

— William Freebairn

Key Belgian political party calls for ambitious new nuclear plant program

- MR party is part of governing coalition
- Call for EDF to operate reactors in Belgium

One of Belgium's main political parties, the Mouvement Reformateur, called July 5 during a press conference for the country to launch an ambitious program of new nuclear construction warning that otherwise the target of carbon neutrality by 2050 will be impossible for the country to reach.

The center-right liberal MR party, active in the French-speaking half of the country, has 14 seats in the 150-seat lower house of parliament and is a member of the current coalition government. It said Belgium should seek to construct up to 12 GW of nuclear power in two stages by 2050.

During the first stage, 8 GW of nuclear capacity should be constructed between 2035 and 2045, mostly as large conventional reactors but also with some small modular reactors, party president Georges-Louis Bouchez said during the press conference.

"From 2040, we envisage a further 2 GW to 4 GW made up of fourth-generation reactors and SMRs," added Marie-Christine Marghem, former Belgian energy minister from 2014 to 2020.

"We need to take a decision now [on construction of the first 8 GW] or during the formation of the next [federal] government," Bouchez said. A commitment to the nuclear construction program will be a condition for the MR to join a future national coalition government, he added.

National elections to the main decision-making lower house of parliament, the Chamber of Representatives, are due to be held June 9, 2024, with lawmakers having a five-year mandate. Belgian national governments are normally wide-ranging coalitions.

Bouchez said that although his party is the only one to have so far come out and made "revolutionary" detailed demands for a new nuclear plant construction program, most other mainstream parties, with the notable exceptions of the country's anti-nuclear Green or Ecolo parties, also realize that Belgium will need new nuclear capacity to reach its climate change goals.

"Numerous studies also show that a mix of renewable energy and nuclear is the cheapest option," Bouchez added.

Bouchez said that the recent agreement between the Belgian government and power company Engie on the extended 10-year operation of the 1,090-MW Doel-4 and 1,094-MW Tihange-3 reactors after 2025 provides the "framework" for Engie to play a role in the construction of new nuclear capacity in the country, especially since the two sides had agreed on how to deal with the problem of nuclear waste.

"Engie could consider that having a nuclear fleet operating for around 80 years is now an attractive prospect," Bouchez said.

If not, the Belgian government could turn to other nuclear power operators to help build the new reactors, such as France's EDF, with EDF possibly even buying Engie's existing Belgian nuclear assets, Bouchez said.

"In 2018, EDF already approached Engie with the idea of taking over its Belgian nuclear assets, so this idea is not completely unrealistic," he added. Any main technology provider for new Belgian reactor capacity should preferably be European, Bouchez said, noting the problems faced by the UK government when they had to extract themselves from parts of a series of agreements with Chinese state company China General Nuclear over CGN's role in the construction of three nuclear plants, in the UK, Sizewell C, Hinkley Point C and Bradwell B.

Marghem also said that land for new units is available at both the existing Doel and Tihange plant sites.

— Chris Johnstone

Ontario releases long-term strategy to meet growing power needs

- Demand could more than double to 88 GW
- Growth driven by economy, electrification

The Ontario government outlined its strategy to meet rising electricity demand, which could more than double to 88 GW by midcentury, with a heavy reliance on building out non-carbon emitting baseload energy such as small modular nuclear reactors, battery storage and hydropower.

The province will also competitively procure more renewable electricity such as wind and solar power, according to the 86-page plan, Powering Ontario's Growth: Ontario's Plan for a Clean Energy Future, released July 10.

The plan addresses projected electricity demand through the 2030s and 2040s, and was created in response to a December 2022 report by the Independent Electricity System Operator (IESO) that explored the path to decarbonization.

Non-carbon emitting generators already provide up to 90% of the province's electricity needs — with nuclear power accounting for about 51% of electric generation in 2022 and hydropower 25% — making a transition away from fossil fuels easier. The main challenge the province wants to address is an expected surge in demand caused by economic growth and electrification. Ontario officials have committed to building 1.5 million new homes by 2031 to help accommodate the growth.

To a degree, the projected increase in electricity demand will be caused by Canada's transition away from fossil fuels for power generation and transportation. Automakers Stellantis NV, Volkswagen AG and Umicore SA have made manufacturing investments in the province, which is also working with the steel industry to end coal use and electrify operations to support green steel production, a July 10 announcement noted.

"These investments alone will increase electricity demand

in the province by 8 terawatt hours, the equivalent of doubling the energy use of the Ottawa region every year," according to the announcement.

At the top of the province's power plan is an effort to expand nuclear power, potentially increasing capacity by 4,800 MW. That includes an effort by power company Ontario Power Generation Inc. to expand the expected operating capacity of its small nuclear reactor project at its Darlington site to 1.2 GW.

And to meet peak demand as nuclear reactors are taken offline for refurbishment, the province is "moving forward with the procurement of clean energy storage and incremental natural gas generation," it said in the plan. Nuclear reactors in Canada require refurbishment after 30 to 40 years of operation. Refurbishments are underway at the Darlington and Bruce A and Bruce B sites.

The IESO is working on procuring up to 2,500 MW of stand-alone energy storage and a maximum of 1,500 MW of natural gas generation, according to the plan. The grid operator is also assessing two proposed pumped hydroelectric storage projects, and preparing a plan to address transmission bottlenecks between northern Ontario and Toronto.

"While during most hours throughout the year Ontario can meet its electricity generation needs with nuclear, hydroelectric, bioenergy, wind and solar power, natural gas generation also acts as the province's insurance policy that can be turned on if the wind is not blowing or the sun is not shining, or another generator is offline for repairs," the province said. Natural gas plants accounted for about 26% of capacity in 2022, but produced slightly over 10% of the province's electricity that year.

Nearly 10% of the province's electricity demand was met with wind energy in 2022, and another 2.5% came from solar.

S&P Global Commodity Insights reporter Justin Horwath produces content for distribution on Capital IQ Pro.

— Justin Horwath

Fusion industry faces hurdles as it seeks tax credits for manufacturing

- Federal credits for clean energy may be open for fusion
- Fusion companies seek part of $4 billion in investment tax credits

The nascent fusion energy industry faces a test this summer on whether it will be treated the same as other clean energy sources in receiving crucial US manufacturing tax credits under the Inflation Reduction Act.

The US Energy Department recently said it will be accepting applications through July 31 from companies looking to qualify for the new section 48c investment tax credit covering clean energy facilities.

The interest in tax credits follows the fusion industry's aggressive commercialization plans that include one company signing a power purchase agreement in May with a customer in the wake of the Nuclear Regulatory Commission's approval of a regulatory framework for the new fusion power plants earlier this year.

NRC staff will meet July 12 to discuss pulling together regulations for the emerging fusion power sector following the commission's framework approval, which the industry has lauded as the best way forward.

The Fusion Industry Association said its members have already begun submitting applications to the DOE and the Treasury Department seeking to qualify for an initial $4 billion in section 48c clean energy investment tax credits. The request for applications marks the first tranche under the Inflation Reduction Act's expanded $10 billion advanced energy tax credit program.

"The applications are out now and due at the end of July," Andrew Holland, CEO of the FIA, said in a June 28 interview. "That's going to be an interesting test to see if they actually fund anything in fusion."

The 48c investment tax credit provides a credit for purchasing and commissioning property to build an industrial or manufacturing facility.

Fusion company officials have said in recent weeks that the clean energy manufacturing incentive program can greatly assist creating a domestic fusion power industry, but only if it treats the technology on par with other zero-carbon emission sources. Over the longer term, there will be opportunities to revisit US tax policy on Capitol Hill to ensure fusion can compete with other energy resources on a level playing field.

Holland said he is being assured by the Biden administration that there should not be any problems with fusion power projects qualifying for the tax credits. But Holland noted that it is an extremely competitive process, with more established solar energy companies and other renewable energy companies pushing hard for the credits to expand their operations in the US.

The industry is also looking to satisfy the requirements for attaining 45x advanced manufacturing production tax credits, which apply to clean energy components domestically produced, according to the DOE.

Holland said a legislative change may be needed to ensure fusion power facilities qualify for 45x, meaning a need for Congress to specifically include fusion under qualifying facilities.

But lobbying for new legislation would be somewhat of a last resort, according to Holland. For now, the industry is focused on leveraging the current suite of federal tax credits and other technology programs to help advance company plans to either build their own reactors or become fusion component manufacturers, Holland said.

One company vying for the manufacturing credits is Helion Energy, which recently signed a power purchase agreement to begin supplying power to Microsoft's corporate footprint and datacenters in Washington state beginning in 2028. To accomplish this, the company also struck a partnership with Exelon subsidiary Constellation, which will serve as the company's energy marketer.

In addition to the fusion reactor developers like Helion, Commonwealth Fusion and General Atomics, the FIA is also working to ensure fusion component manufacturers are

receiving support under the CHIPS and Science Act that was also signed into law in 2022. The law provides nearly $280 billion in new funding in support of the domestic semiconductor industry.

Although the CHIPS law is not specifically focused on energy, Holland said it will go a long way toward creating a fusion component supply chain that will directly benefit the reactor developers.

The CHIPS Act is focused on semiconductors, which is a relevant technology for pulse fusion. The Commerce Department is taking the lead on distributing the funds, establishing the new CHIPS program office to handle the awards and a new research and development office housed within the agency's National Institute of Standards and Technology.

The focus with CHIPS is for the industry to establish a reliable technology supply network in the US that would make it less dependent on suppliers from China.

Import substitution

The path forward could be somewhat tricky on this front. Holland said that in the near term, the industry has no choice but to rely on Chinese imports for some components. But in the long term, reducing the industry's reliance on Chinese imports will be preferable.

Because of this, the industry is looking to get involved in talks on Capitol Hill about any stiff action against China. For now, the industry is advising a light touch until the US can build up its manufacturing base to support a fusion power industry with the components it needs, Holland said.

"The cake isn't baked yet, so we need to get our supply chains right," Holland said. Once the US has the capacity to withstand any likely Chinese retaliation for increasing US tariffs on Chinese goods, stronger measures can be applied.

Once a strong supply chain is in place, Helion has said it envisions establishing large-scale manufacturing plants, able to produce reactors to be deployed globally.

In the meantime, the company has said it is on track to reach its next milestone in 2024, when it hopes to demonstrate that it can generate electricity from its seventh-generation Polaris prototype fusion reactor.

If achieved, it would be the first fusion power generator to demonstrate what is known as net electricity generation. This means it can produce more electricity than what it takes to generate it. Achieving such a milestone is key for making fusion commercial and competitive with existing power resources.

Commonwealth Fusion, in collaboration with the Massachusetts Institute of Technology, has said it is scheduled to achieve net energy from fusion with its SPARC reactor in 2025. Its first commercial plant, called ARC, is scheduled to be completed in the early 2030s. Both Helion and Commonwealth have received billions in private investment capital as well as awards from the DOE.

— John Siciliano

Spanish election could open the door to nuclear life extensions ...from page 1

The PP is presently expected to win the popular vote, according to the latest polls, but it may not obtain a full majority.

The PP's largest ally in the elections, right-wing populist party Vox, which has yet to present its formal plan on nuclear energy, is also against the closure plan, which was approved under the current left-wing PSOE-led government. Vox has called the closures "energy suicide," seeing nuclear power as a key tool for energy sovereignty and electricity price control in Spain.

In 2021, Vox put forward a parliamentary motion to provide Spain's nuclear plants with a fixed income. The motion was rejected by the PSOE government.

The latest opinion polls estimate PP might win around 140 to 145 seats and Vox around 35 to 40 in the country's legislature. A total 176 seats are required to form a majority.

The socialist PSOE government presented the closure plan in 2019 after lengthy negotiations with the two main plant operators, Spanish-controlled group Iberdrola and Endesa, controlled by Italy's Enel.

Spanish nuclear plants

Name	Capacity (MW)	Reactor type	Operator	Start date	Closure date
Almaraz-1	1,049	PWR	Iberdrola 53%, Endesa 36%, Naturgy 11%	1980	2027
Almaraz-2	1,044	PWR	Iberdrola 53%, Endesa 36%, Naturgy 11%	1983	2028
Asco-1	1,032	PWR	Endesa 100%	1982	2029
Cofrentes	1,092	BWR	Iberdrola 100%	1984	2030
Asco-2	1,027	PWR	Endesa 85%, Iberdrola 15%	1985	2033
Vandellos-2	1,087	PWR	Endesa 72%, Iberdrola 28%	1987	2034
Trillo	1,066	PWR	Iberdrola 48%, Naturgy 34%, EDP 16%, Nuclenor 2%	1987	2035

Source: Foro Nuclear, Consejo de Seguridad Nuclear

PSOE oversaw the most recent closure of a nuclear unit in Spain, the 466-MW Garona boiling water reactor, which had been in operation for 42 years when it closed in 2013. The unit was operated by a joint venture between Iberdorla and Endesa.

Ecological Transition Minister Teresa Ribera of the PSOE denounced the PP's life extension plans as a campaign "trick" in a presentation June 28, attacking the opposition for not having a clear expenditure plan for life extension.

"We are not prepared to invest large sums of money for something that has a limited lifespan, which, if it exceeds its timeframes, requires a larger amount than we are prepared to support," Ribera said.

The closure plan was previously estimated to cost Eur15 billion ($16.30 billion) to 2035 by nuclear dismantling group Enresa, while a plan for seven decentralized long-term waste storage sites is likely to cost a further Eur27 billion up to 2100.

In July 4 comments to reporters, Ribera described the PP's stance as a "backwards step." The party confirmed its

commitment to the closure plan when it delivered Spain's National Energy and Climate Plan to the European Commission at the end of June.

Almaraz battle

With the political opposition leading in the polls, the first reactor closure battleground is expected to be at the Almaraz nuclear plant, where the 1,049-MW Almaraz-1 is due to shut in 2027, with the 1,044-MW Almaraz-2 scheduled to close a year later, in 2028.

The PP has signed an agreement to share control of the Extremadura regional government with the more hard-line Vox party, including a clear message to its ally regarding the nuclear plant. Almaraz is within the Extremadura region.

In the 60-point document, the parties agreed to "protect the energy and industrial assets threatened by ideological reasons," including "rectify[ing] the dismantling plan for the Almaraz nuclear plant."

The first closure milestone would be as soon as October 2024, a date by which the regulator CSN must start initial procedures to plan the closure of the two reactors.

However, any reversal would require fresh negotiations with the nuclear plant operators, and a potential change in the financial regime that governs the nuclear energy sector in Spain.

The two companies have generally been flexible in their approach to the subject.

Iberdrola's CEO Ignacio Sanchez Galan told reporters May 31 that the company was open to keeping plants operating for longer, Spanish newspaper Expansion reported. Galan has said several times that the main criteria for the company is that the business remain profitable.

Meanwhile Endesa, which initially pushed for a longer timeframe for the closures in order to fit its 50-year amortization period, is also, according to local media reports, in favor of a life extension, with both parties reportedly sounded out by the PP in recent weeks.

The amortization period means the time period over which the company has accounted for paying off the financing of the assets in question. Endesa previously estimated a cost of Eur190 million per year if the plants were closed before reaching 50 years of operation.

— Gianluca Baratti

Norwegian company sees potential for SMRs as country debates nuclear energy ...from page 1

businessmen who have been involved in the oil and gas industry. Hesthammer's background is also in oil and gas.

Norway has never had commercial nuclear power but the country had three research reactors, Halden, Jeep I and Jeep II. All are permanently shut and plans are being developed for final storage of the reactors' spent fuel.

There is also a nuclear regulator, the Norwegian Radiation and Nuclear Safety Authority, which reports to the Climate and Environment and the Health and Care Services ministries.

Hesthammer said that if Norway begins a commercial reactor program the authority could be expanded and financed through a combination of public money and fees paid by reactor owners.

Norway considered commercial nuclear power in the late 1960s and through the 1970s, going so far as to develop plans for a reactor in the Oslo region. However, in 1979 following the Three Mile Island accident the Norwegian parliament decided the country should focus on hydropower rather than nuclear power.

But with uncertainty over energy supply caused by the war in Ukraine, higher electricity prices and concern about climate change, Hesthammer said "what we are seeing is a change" in the attitude toward nuclear power in Norway.

Almost all of Norway's electricity comes from hydropower which is in plentiful supply in the country. However, carbon dioxide emissions are still relatively high because of the transportation sector and the oil and gas industry.

In February, three MPs asked the government to consider developing commercial nuclear power. The multi-party Energy and Environment Committee in the Norwegian Parliament subsequently outlined a plan to the full parliament for nuclear power research and development.

In response, Oil and Energy Minister Terje Aasland, a member of the Labor party, said in a series of statements to parliament in February, March and April that "the government's main focus is on renewable energy and nuclear power is not today under consideration as a means of generation for Norwegian electricity production."

In February an energy commission appointed by the government delivered a report on Norway's future energy policy and potential generation sources. Of the 15 commission members, 11 said that "nuclear power is not a solution for Norway now, but Norway should continuously follow international developments in nuclear power technology."

Norway has thorium deposits and there have been attempts by Norwegian commercial companies to develop thorium as a fuel for nuclear reactors. In their comment to the government, the MPs and the committee said thorium should be researched again as a potential nuclear fuel.

But Aasland said that thorium is not a realistic alternative for energy production in Norway.

"A commercial reactor which uses thorium as fuel would be expensive to develop and [is a technology] that is many years in the future," he said.

Political change needed

Hesthammer acknowledged that political change is needed if reactors are to be built, but said he thinks that is possible.

Since the Halden and Jeep II research reactors were shut, research has been going on into the best solution for a final repository for spent nuclear fuel. Hesthammer said that if SMRs are built, Norsk Kjernekraft could help offset the cost of a repository since it could use a repository for spent fuel from its reactors as well.

"Norway has nuclear waste. We can't just run away from it. Norway has to build a waste facility. We are saying collaborate with Norsk Kjernekraft."

Building and licensing commercial reactors in Norway would require legal changes. Hesthammer said Norsk Kjernekraft is working toward getting those changes through parliament. In addition, the parliament would likely have to give approval before construction of any reactor could begin.

In the interim, the company is focusing on preliminary site selection and potential designs.

At an April meeting, the northern Norway municipal council of Vardo approved a collaboration with Norsk Kjernekraft. In the minutes of the meeting, the council said that Vardo is "positive toward further investigation of nuclear power with a clear intention to establish a SMR in Svartnes." Svartnes is a village within the municipality.

However, Labor Councilor Torbjorn Leistad said that the local Labor party wanted an advisory referendum before any decision was made to go ahead with a reactor.

Norsk Kjernekraft also has agreements with three other Norwegian municipalities on potentially siting reactors. Hesthammer said the company has had discussions with other municipalities as well.

In June, the company signed an agreement with Norwegian nickel producer Glencore Nikkelverk to deliver nuclear power generated electricity to Glencore.

Also in June, Norsk Kjernekraft it signed an agreement with TVO Nuclear Services, the commercial arm of Finnish power company Teollisuuden Voima Oy, on nuclear power cooperation. A memorandum of understanding on nuclear development was signed with Rolls-Royce SMR in March.

In a statement announcing the agreement, the two companies said they "want to work together to increase acceptance of nuclear power in Norway, and to potentially establish future projects that could lead to the deployment of Rolls-Royce's small, modular nuclear power plants in Norway."

Norsk Kjernekraft also expects to sign an agreement with the Danish company Seaborg Technologies this week. Seaborg is developing molten salt reactor technology.

Hesthammer said that if Norsk Kjernekraft does not get approval to build reactors, the expertise it is developing can still be commercially useful. He said the company could provide consulting services, for instance in neighboring Sweden where a new government has recently opened up the potential for additional nuclear power.

Research centers also considered

Separately, in January FME Renewclear, a group led by the Norwegian University of Science and Technology (NTNU), said it wants to establish nuclear research centers, and has applied to the Research Council of Norway for partial funding. FME already researches other types of energy production, carbon capture and storage and energy efficiency.

The group said it wants to set up six to ten research centers with a total budget of NOK 1.2 billion ($113 million). The group said it wants to research SMRs as well as combined heat and power reactors, among other projects. Projects would run for three to six years.

The FME group includes Norsk Kjernekraft. State-owned oil and gas company Equinor and partially state-owned aluminum maker Norsk Hydro have also said they are interested in participating in the project, Jonas Kristiansen Noland said in an email July 11. Noland is an associate professor at NTNU and is involved in FME and other nuclear research projects.

Legally, however, the research council cannot fund nuclear research. Noland said FME submitted its application for funding in the hope that the law will be changed. If the council is allowed to fund the research, it expects to make a decision on FME's application in April.

— Ariane Sains

Notes to Nucleonics Week generating tables for May 2023

In France, Blayais-4 returned June 17 after shutting Feb. 11 for refueling; Bugey-5 refueled from May 6 to June 24; Cattenom-2 shut for refueling March 3 and remained offline; Chinon-B1 shut for refueling Feb. 7 and remained offline; Chinon-B3 shut May 2 for refueling and remained offline; Chinon-B4 shut Feb. 25, returning May 10; Dampierre-1 returned June 13 after shutting for refueling Feb. 26; Dampierre-4 shut for refueling May 31 and remained offline; Cruas-4 remained offline for refueling that began May 28; Gravelines-1 shut Feb. 11 for refueling, remaining offline; Gravelines-6 remained shut after refueling began there April 18; Golfech-2 shut for refueling March 27 and remained offline; Nogent-2 shut April 15 and returned July 11; Paluel-1 shut Feb. 17, returning May 28; Paluel-3 remained offline after shutting April 28 for refueling; St. Alban-1 remained offline after shutting Feb. 24 for refueling; St. Laurent-2 shut Jan. 20 for refueling and remained offline; Tricastin-4 returned June 19 from refueling that began April 20.

In Japan, Ikata-3 shut Feb. 23 for refueling, returning May 26; Sendai-2 remained offline after shutting for refueling May 13.

In Spain, Almaraz-1 shut for refueling early April 17, returning May 20; Asco-1 returned late June 15 from refueling that began April 29; Trillo returned June 23 from refueling that began May 24.

In the US, Arkansas Nuclear One-2 returned early May 23 from refueling that began April 15; Braidwood-2 shut April 24 for refueling, returning May 13; Columbia returned June 19, ending a refueling outage that began May 5; Comanche Peak-2 refueled from April 24 to May 28 or May 29; Ginna shut April 9 for refueling, returning May 1; Limerick-2 returned May 19 from refueling that began May 1; Monticello returned May 14 from refueling that began April 17; Palo Verde-2 refueled from April 7 to May 13; Summer shut April 5 for refueling, returning May 19; Surry-2 returned June 8 from refueling that began April 23; Turkey Point-3 shut April 10 for refueling, returning May 6; Watts Bar-1 returned May 12 from refueling that began April 17.

Long-term outages

France's Civaux-1 shut in August 2021 for an overhaul and refueling, and returned Jan. 25 after repairs related to indications of stress corrosion cracking discovered in safety-related piping. Inspections showed similar defects in Civaux-2, which shut in November 2021 and returned April 23; Chooz B-1 and B-2 shut in mid-December of that year for the same reason. Chooz B-2 returned Feb. 8 and Chooz B-1 returned May 11. Penly-1 has been shut since October 2021 for similar checks and repairs, and Penly-2 shut in August 2022 while it too undergoes inspections related to the potential cracking. Penly-2 returned June 16. Cattenom-3, which shut in March 2022 to address a stress corrosion issue and replace a reactor coolant pump, returned April 18. Golfech-1 remained offline after being shut Feb. 26, 2022 for refueling. Flamanville-1 shut March 22, 2023 for a steam generator replacement and remained offline. Blayais-1 shut for refueling and upgrades July 31, 2022, returning June 20.

Japan had no nuclear generation from mid-September 2013, when the last of its operational units was shut for refueling and maintenance, until Sendai-1 was connected to the grid in August 2015 and Sendai-2 was connected to the grid two months later. Takahama-3, Takahama-4 and Ikata-3 restarted in 2016 and 2017 respectively. Ohi-3 and -4 returned to service in 2018, as did Genkai-3 and -4. Mihama-3 returned to service in June 2021. The other operational units remain shut following the March 11, 2011 earthquake and tsunami that resulted in the permanent shutdown of all six units at Fukushima I. Three of Japan's power reactors — Kashiwazaki-Kariwa-2, -3 and -4 — have been shut since a major earthquake in Niigata prefecture July 16, 2007.

— Staff

Nuclear Electricity Generation for May 2023

Gross capacity of each unit listed hereunder is to the best of our knowledge the turbine nameplate rating unless we have evidence that some other figure more justly reflects our purpose of showing the unit s performance in relation to what the seller and buyer felt the unit was bought, designed, built, and intended to do.

COUNTRY: Plant	Capacity MW gross	MWh gross in May	Capacity factor May	Total MWh gross in 2023	Capacity factor 2023	Lifetime total MWh gross
Argentina						
Atucha-1	362	243,898	90.56	1,173,442	89.45	111,282,869
Atucha-2	745	0	0.00	0	0.00	25,819,910
Embalse (#)	648	NA				134,716,956
Total. Argentina	**1,755**	**243,898**		**1,173,442**		
Armenia						
Metsamor-2 (#)	448	(a)		1,245,445	96.53	86,645,142
Belgium						
Doel-1	454	329,667	97.60	1,691,754	102.85	149,182,841
Doel-2	454	346,235	102.50	1,361,166	82.75	147,369,853
Doel-4	1,090	41,058	5.06	2,847,891	72.12	298,131,492
Tihange-1	1,009	745,725	99.34	3,670,503	100.41	325,877,008
Tihange-2	1,055	0	0.00	749,373	19.61	282,800,780
Tihange-3	1,094	809,163	99.45	3,941,842	99.49	308,664,752
Total. Belgium	**5,156**	**2,271,848**		**14,262,529**		
Brazil						
Angra-1	640	484,398	101.73	2,301,863	99.25	131,785,000
Angra-2	1,350	1,010,017	100.56	4,518,789	92.36	227,706,281
Total. Brazil	**1,990**	**1,494,415**		**6,820,652**		
Bulgaria (Lifetime only from May 1993)						
Kozloduy-5	1,000	0	0.00	3,033,969	83.72	129,264,258
Kozloduy-6	1,000	546,338	73.43	3,653,085	100.80	129,063,035
Total. Bulgaria	**2,000**	**546,338**		**6,687,054**		
Canada						
Bruce-1 (#)	904	NA				100,745,474
Bruce-2 (#)	904	NA				80,852,078
Bruce-3 (#)	805	NA				152,933,281
Bruce-4 (#)	805	NA				147,809,379
Bruce-5 (#)	872	NA				174,080,993
Bruce-6 (#)	891	NA				170,022,252
Bruce-7 (#)	872	NA				167,181,306
Bruce-8 (#)	845	NA				156,441,261
Darlington-1 (#)	934	NA				205,609,210
Darlington-2 (#)	934	NA				173,451,557
Darlington-3 (#)	934	NA				196,543,177
Darlington-4 (#)	934	NA				194,313,358
Pickering-1 (#)	542	NA				129,345,967
Pickering-4 (#)	542	NA				134,449,010
Pickering-5 (#)	540	NA				133,383,678
Pickering-6 (#)	540	NA				138,251,314
Pickering-7 (#)	540	NA				133,180,978
Pickering-8 (#)	540	NA				125,313,099
Point Lepreau (#)	680	NA				123,941,586
Total. Canada	**14,558**					
China						
Daya Bay-1 (#)	984	NA				148,002,066
Daya Bay-2 (#)	984	NA				146,831,541
Hongyanhe-1 (#)	1,119	NA				0
Hongyanhe-2 (#)	1,119	NA				0
Ling Ao I-1 (#)	990	NA				65,890,643
Ling Ao I-2 (#)	990	NA				65,917,069
Ling Ao I-3 (#)	1,080	NA				37,277,112
Ling Ao I-4 (#)	1,080	NA				31,807,530
Ningde-1 (#)	1,089	NA				0
Ningde-2 (#)	1,089	NA				0
Qinshan I (#)	310	NA				NA

Nuclear Electricity Generation (continued)

COUNTRY: Plant	Capacity MW gross	MWH Gross in May	Capacity Factor May	Total MWH Gross in 2023	Capacity Factor 2023	Lifetime Total MWh gross
Qinshan II (3 units) (#)	1,950	NA				NA
Qinshan III (2 units) (#)	1,456	NA				NA
Tianwan-1 (#)	1,000	NA				NA
Tianwan-2 (#)	1,000	NA				NA
Yangjiang-1 (#)	1,086	NA				0
Total. China	**17,326**					
Czech Republic						
Dukovany-1 (#)	498	(a)		1,416,623	98.81	126,781,829
Dukovany-2 (#)	498	(a)		710,978	49.59	121,217,993
Dukovany-3 (#)	498	(a)		1,432,566	99.92	120,720,747
Dukovany-4 (#)	498	(a)		1,445,447	100.82	121,612,193
Temelin-1	1,086	0	0.00	2,557,627	65.00	147,198,745
Temelin-2	1,086	841,314	104.13	3,931,555	99.92	143,078,641
Total. Czech Republic	**4,164**	**841,314**		**11,494,796**		
Finland						
Loviisa-1	531	385,434	97.56	1,908,376	99.20	176,297,595
Loviisa-2	531	387,126	97.99	1,920,220	99.81	166,228,201
Olkiluoto-1	910	656,948	97.03	3,085,064	93.57	294,963,848
Olkiluoto-2	890	236,295	35.69	2,822,994	87.55	284,813,119
Total. Finland	**2,862**	**1,665,803**		**9,736,654**		
France (Note: EDF says capacity factor may not be the best measure of performance due to extensive load-following dictated by the national grid.)						
Belleville-1 (#)	1,363	NA				228,429,868
Belleville-2 (#)	1,363	NA				228,372,049
Blayais-1 (#)	951	NA				202,087,096
Blayais-2 (#)	951	NA				206,335,553
Blayais-3 (#)	951	NA				202,343,868
Blayais-4 (#)	951	NA				198,815,152
Bugey-2 (#)	945	NA				206,252,904
Bugey-3 (#)	945	NA				197,933,503
Bugey-4 (#)	917	NA				202,188,053
Bugey-5 (#)	917	NA				203,028,227
Cattenom-1 (#)	1,362	NA				235,351,806
Cattenom-2 (#)	1,362	NA				236,828,640
Cattenom-3 (#)	1,362	NA				215,217,578
Cattenom-4 (#)	1,362	NA				213,977,301
Chinon-B1 (#)	954	NA				192,227,786
Chinon-B2 (#)	954	NA				188,727,900
Chinon-B3 (#)	954	NA				173,840,581
Chinon-B4 (#)	954	NA				168,650,847
Chooz-B1 (#)	1,560	NA				154,806,893
Chooz-B2 (#)	1,560	NA				149,855,478
Civaux-1 (#)	1,561	NA				133,531,868
Civaux-2 (#)	1,561	NA				133,830,965
Cruas-1 (#)	956	NA				186,342,389
Cruas-2 (#)	956	NA				183,766,320
Cruas-3 (#)	956	NA				183,922,409
Cruas-4 (#)	956	NA				179,592,122
Dampierre-1 (#)	937	NA				205,187,678
Dampierre-2 (#)	937	NA				198,052,176
Dampierre-3 (#)	937	NA				205,091,711
Dampierre-4 (#)	937	NA				195,892,290
Flamanville-1 (#)	1,382	NA				242,098,146
Flamanville-2 (#)	1,382	NA				244,396,152
Golfech-1 (#)	1,363	NA				220,883,113
Golfech-2 (#)	1,363	NA				192,118,925
Gravelines-B1 (#)	951	NA				201,579,617
Gravelines-B2 (#)	951	NA				210,101,621
Gravelines-B3 (#)	951	NA				207,605,537
Gravelines-B4 (#)	951	NA				209,717,377
Gravelines-C5 (#)	951	NA				191,075,230

Nuclear Electricity Generation (continued)

COUNTRY: Plant	Capacity MW gross	MWH Gross in May	Capacity Factor May	Total MWH Gross in 2023	Capacity Factor 2023	Lifetime Total MWh gross
Gravelines-C6 (#)	951	NA				189,785,176
Nogent-1 (#)	1,363	NA				234,133,280
Nogent-2 (#)	1,363	NA				231,298,622
Paluel-1 (#)	1,382	NA				259,218,770
Paluel-2 (#)	1,382	NA				255,423,577
Paluel-3 (#)	1,382	NA				243,708,869
Paluel-4 (#)	1,382	NA				249,049,693
Penly-1 (#)	1,382	NA				223,669,193
Penly-2 (#)	1,382	NA				208,598,560
St.Alban/St.Maurice-1 (#)	1,381	NA				239,254,125
St.Alban/St.Maurice-2 (#)	1,381	NA				233,660,201
St.Laurent-des-Eaux B1 (#)	956	NA				195,403,881
St.Laurent-des-Eaux B2 (#)	956	NA				192,544,266
Tricastin-1 (#)	955	NA				211,559,906
Tricastin-2 (#)	955	NA				208,756,321
Tricastin-3 (#)	955	NA				213,145,047
Tricastin-4 (#)	955	NA				208,005,690
Total. France	**64,040**					
Germany						
Emsland *** (#)	1,406			2,245,050	55.46	393,836,562
Isar-2 *** (#)	1,485			3,024,036	70.73	404,733,239
Neckar-2 *** (#)	1,400			1,946,550	48.29	375,521,489
Total. Germany	**4,291**			**7,215,636**		
Hungary						
Paks-1	509	375,937	99.35	1,850,430	100.42	147,842,126
Paks-2	506	374,888	99.58	1,533,154	83.63	136,855,678
Paks-3	506	0	0.00	1,418,591	77.38	134,059,016
Paks-4	506	275,400	73.15	1,738,643	94.84	133,545,376
Total. Hungary	**2,027**	**1,026,225**		**6,540,818**		
India						
Kaiga-1	220	157,000	95.92	764,000	95.83	34,459,566
Kaiga-2	220	165,000	100.81	805,000	100.97	35,068,748
Kaiga-3	220	96,000	58.65	777,000	97.46	23,886,000
Kaiga-4	220	178,000	108.75	843,000	105.73	21,782,000
Kakrapar-1	220	164,000	100.20	811,000	101.72	36,025,941
Kakrapar-2	220	156,000	95.31	789,000	98.96	38,144,594
Kudankulam-1	1,000	727,000	97.72	3,414,000	94.21	45,830,000
Kudankulam-2	1,000	110,000	14.78	2,723,000	75.14	33,360,000
Madras-1	220	0	0.00	0	0.00	35,229,243
Madras-2	220	169,000	103.25	789,000	98.96	43,437,103
Narora-1	220	130,000	79.42	746,000	93.57	40,291,290
Narora-2	220	155,000	94.70	777,000	97.46	39,791,164
Rajasthan-1	100	0	0.00	0	0.00	11,960,915
Rajasthan-2	200	117,000	78.63	370,000	51.05	45,287,785
Rajasthan-3	220	0	0.00	0	0.00	35,508,928
Rajasthan-4	220	149,000	91.03	711,000	89.18	35,987,972
Rajasthan-5	220	171,000	104.47	609,000	76.38	24,063,000
Rajasthan-6	220	165,000	100.81	822,000	103.10	21,620,000
Tarapur-1	160	0	0.00	0	0.00	49,276,775
Tarapur-2	160	0	0.00	0	0.00	50,954,928
Tarapur-3	540	403,000	100.31	1,936,000	98.93	63,455,000
Tarapur-4	540	284,000	70.69	1,264,000	64.59	61,106,265
Total. India	**6,780**	**3,496,000**		**18,950,000**		
Japan						
Genkai-3	1,180	899,446	102.45	4,374,228	102.29	191,595,441
Genkai-4	1,180	890,662	101.45	3,148,554	73.63	167,874,422
Hamaoka-3	1,100	0	0.00	0	0.00	179,146,924
Hamaoka-4	1,137	0	0.00	0	0.00	143,839,198
Hamaoka-5	1,380	0	0.00	0	0.00	35,989,175
Higashidori-1	1,100	0	0.00	0	0.00	41,030,051

Nuclear Electricity Generation (continued)

COUNTRY: Plant	Capacity MW gross	MWH Gross in May	Capacity Factor May	Total MWH Gross in 2023	Capacity Factor 2023	Lifetime Total MWh gross
Ikata-3	890	87,607	13.23	1,253,656	38.87	140,444,770
Kashiwazaki-Kariwa-1	1,100	0	0.00	0	0.00	167,491,230
Kashiwazaki-Kariwa-2	1,100	0	0.00	0	0.00	125,113,550
Kashiwazaki-Kariwa-3	1,100	0	0.00	0	0.00	104,978,640
Kashiwazaki-Kariwa-4	1,100	0	0.00	0	0.00	93,439,420
Kashiwazaki-Kariwa-5	1,100	0	0.00	0	0.00	142,874,170
Kashiwazaki-Kariwa-6	1,356	0	0.00	0	0.00	133,976,546
Kashiwazaki-Kariwa-7	1,356	0	0.00	0	0.00	117,915,082
Mihama-3	826	646,898	105.26	3,152,057	105.30	188,273,685
Ohi-3	1,180	909,421	103.59	4,444,783	103.94	216,479,237
Ohi-4	1,180	908,630	103.50	4,439,415	103.81	224,591,514
Onagawa-2	825	0	0.00	0	0.00	82,855,326
Onagawa-3	825	0	0.00	0	0.00	45,459,784
Sendai-1	890	710,001	107.22	1,900,516	58.92	226,581,275
Sendai-2	890	280,579	42.37	3,036,734	94.15	219,066,247
Shika-1	540	0	0.00	0	0.00	61,466,824
Shika-2	1,206	0	0.00	0	0.00	27,362,972
Shimane-2	820	0	0.00	0	0.00	134,337,331
Takahama-1	826	0	0.00	0	0.00	185,812,942
Takahama-2	826	0	0.00	0	0.00	183,722,641
Takahama-3	870	683,546	105.60	3,341,509	105.98	208,394,726
Takahama-4	870	687,073	106.15	2,136,808	67.77	204,923,829
Tokai-2	1,100	0	0.00	0	0.00	229,838,671
Tomari-1	579	0	0.00	0	0.00	96,110,274
Tomari-2	579	0	0.00	0	0.00	88,148,481
Tomari-3	912	0	0.00	0	0.00	17,911,335
Tsuruga-2	1,160	0	0.00	0	0.00	194,628,260
Total. Japan	**33,083**	**6,703,863**		**31,228,260**		
Mexico						
Laguna Verde-1 (#)	810	NA				152,121,002
Laguna Verde-2 (#)	810	NA				136,367,732
Total. Mexico	**1,620**					
Netherlands						
Borssele-1	515	367,905	96.02	1,461,883	78.35	179,817,957
Pakistan						
Chasnupp-1	325	240,024	99.27	1,088,046	92.38	50,367,874
Chasnupp-2	325	66,306	27.42	981,504	83.33	28,646,237
Chasnupp-3	340	224,260	88.65	1,167,650	94.76	12,272,270
Chasnupp-4	340	251,250	99.32	1,026,684	83.32	13,846,170
Kanupp-2	1,100	703,510	85.96	3,359,494	84.27	15,796,538
Kanupp-3	1,100	0	0.00	2,344,728	58.82	8,825,574
Total. Pakistan	**3,530**	**1,485,350**		**9,968,106**		
Romania						
Cernavoda-1 (#)	706	NA				139,451,578
Cernavoda-2 (#)	706	NA				80,936,820
Total. Romania	**1,412**					
Russia (Lifetime only from March 1993)						
Balakovo-1 (#)	1,000	NA				195,257,250
Balakovo-2 (#)	1,000	NA				188,213,160
Balakovo-3 (#)	1,000	NA				192,230,420
Balakovo-4 (#)	1,000	NA				202,195,120
Beloyarsk-3 (#)	600	NA				114,989,563
Beloyarsk-4 (#)	885	NA				28,880,312
Bilibino-2 (#)	12	NA				1,337,060
Bilibino-3 (#)	12	NA				1,359,930
Bilibino-4 (#)	12	NA				1,270,430
Kalinin-1 (#)	1,000	NA				191,259,973
Kalinin-2 (#)	1,000	NA				201,657,230
Kalinin-3 (#)	1,000	NA				124,569,359
Kalinin-4 (#)	1,000	NA				78,667,102

Nuclear Electricity Generation (continued)

COUNTRY: Plant	Capacity MW gross	MWH Gross in May	Capacity Factor May	Total MWH Gross in 2023	Capacity Factor 2023	Lifetime Total MWh gross
Kola-1 (#)	440	NA				63,000,650
Kola-2 (#)	440	NA				61,591,687
Kola-3 (#)	440	NA				72,252,350
Kola-4 (#)	440	NA				75,180,946
Kursk-2 (#)	1,000	NA				154,585,090
Kursk-3 (#)	1,000	NA				184,512,060
Kursk-4 (#)	1,000	NA				191,939,889
Leningrad-3 (#)	1,000	NA				168,633,957
Leningrad-4 (#)	1,000	NA				173,814,040
Leningrad II-1 (#)	1,188	NA				27,569,864
Leningrad II-2 (#)	1,188	NA				5,852,286
Novovoronezh-4 (#)	417	NA				78,360,810
Novovoronezh-5 (#)	1,000	NA				169,093,120
Novovoronezh II-1 (#)	1,180	NA				37,425,210
Novovoronezh II-2 (#)	1,180	NA				16,979,140
Lomonosov-1 (#)	35	NA				151,668
Lomonosov-2 (#)	35	NA				153,446
Smolensk-1 (#)	1,000	NA				182,294,938
Smolensk-2 (#)	1,000	NA				184,095,168
Smolensk-3 (#)	1,000	NA				196,679,153
Volgodonsk-1 (#)	1,042	NA				163,203,100
Volgodonsk-2 (#)	1,000	NA				92,074,173
Volgodonsk-3 (#)	1,000	NA				48,290,750
Volgodonsk-4 (#)	1,030	NA				31,704,662
Total. Russia	**29,576**					
Slovakia(Slovenske Electrarne s new owner - ENEL Company - has temporarily declined to provide monthly generation data.)						
Bohunice-3 (#)	505	NA				73,571,995
Bohunice-4 (#)	505	NA				72,119,430
Mochovce-1 (#)	470	NA				33,763,932
Mochovce-2 (#)	500	NA				32,654,261
Total. Slovakia	**1,980**					
Slovenia						
Krsko	727	542,362	100.27	2,651,915	100.68	210,729,211
South Africa						
Koeberg-1	970	0	0.00	0	0.00	235,073,894
Koeberg-2	940	715,220	102.27	3,409,181	100.08	230,262,055
Total. South Africa	**1,910**	**715,220**		**3,409,181**		
South Korea						
Hanbit-1	1,025	744,247	97.59	3,689,000	98.55	269,558,437
Hanbit-2	1,024	761,300	99.93	3,737,364	100.40	258,854,040
Hanbit-3	1,041	784,543	101.30	3,797,809	100.21	200,904,429
Hanbit-4	1,041	780,880	100.82	3,802,173	100.17	176,790,711
Hanbit-5	1,051	0	0.00	1,106,266	28.98	156,283,306
Hanbit-6	1,053	781,256	99.72	2,434,224	63.79	159,435,567
Hanul-1	1,014	759,387	100.66	3,679,718	100.14	257,953,099
Hanul-2	1,011	0	0.00	1,241,815	33.87	252,646,987
Hanul-3	1,051	784,443	100.32	1,838,350	48.27	193,815,437
Hanul-4	1,052	784,374	100.22	2,133,226	55.91	174,481,975
Hanul-5	1,049	781,585	100.14	2,420,847	63.58	152,121,414
Hanul-6	1,049	780,103	99.95	3,792,850	99.62	148,576,595
Kori-2	681	0	0.00	1,596,779	64.70	195,467,213
Kori-3	1,046	0	0.00	1,991,310	52.53	273,736,114
Kori-4	1,046	0	0.00	1,575,661	41.57	274,053,235
Saeul 1 (formerly Shin Kori-3)	1,488	0	0.00	3,700,356	68.62	66,683,347
Saeul 2 (formerly Shin Kori-4)	1,491	1,107,216	99.81	5,369,767	99.22	40,083,955
Shin Hanul-1	1,455	1,109,992	102.54	5,402,351	102.45	6,296,915
Shin Kori-1	1,048	784,552	100.62	3,823,400	100.67	84,431,122
Shin Kori-2	1,047	784,256	100.68	3,815,003	100.54	82,932,543
Shin Wolsong-1	1,048	781,862	100.28	2,422,288	63.73	81,827,785
Shin Wolsong-2	1,048	780,302	100.08	3,798,109	99.70	61,059,483

Nuclear Electricity Generation (continued)

COUNTRY: Plant	Capacity MW gross	MWH Gross in May	Capacity Factor May	Total MWH Gross in 2023	Capacity Factor 2023	Lifetime Total MWh gross
Wolsong-2	599	451,367	101.28	1,454,419	57.08	138,633,153
Wolsong-3	624	470,895	101.43	2,303,110	89.83	132,657,331
Wolsong-4	589	445,490	101.66	1,561,173	61.45	130,976,953
Total. South Korea	**25,671**	**14,458,050**		**72,487,368**		
Spain						
Almaraz-1	1,049	235,362	30.14	2,825,547	74.32	301,928,884
Almaraz-2	1,044	728,767	93.78	3,684,127	97.36	298,448,487
Asco-1	1,032	0	0.00	2,595,580	69.39	292,847,021
Asco-2	1,027	771,210	100.91	3,757,530	100.97	287,013,293
Cofrentes	1,092	810,277	99.73	3,918,903	99.05	310,178,430
Trillo	1,066	576,513	72.69	3,530,630	91.42	283,850,773
Vandellos-2	1,087	802,633	99.23	3,854,492	97.86	271,080,435
Total. Spain	**7,399**	**3,924,762**		**24,166,809**		
Sweden						
Forsmark-1	1,022	732,058	96.28	3,155,852	85.23	308,720,581
Forsmark-2	1,158	749,369	86.98	3,948,970	94.13	308,627,604
Forsmark-3	1,208	765,555	85.18	4,269,933	97.56	334,589,714
Oskarshamn-3	1,450	0	0.00	3,305,329	62.92	333,014,528
Ringhals-3 (#)	1,128	(a)		3,269,026	100.66	288,690,358
Ringhals-4 (#)	1,180	(a)		737,469	21.71	278,026,529
Total. Sweden	**7,146**	**2,246,982**		**18,686,579**		
Switzerland						
Beznau-1	380	140,363	49.65	1,241,994	90.21	140,310,052
Beznau-2	380	280,101	99.07	1,373,155	99.74	147,921,603
Goesgen	1,060	659,918	83.68	3,727,939	97.07	350,586,514
Leibstadt	1,285	7,526	0.79	3,686,991	79.20	326,225,378
Total. Switzerland	**3,105**	**1,087,908**		**10,030,079**		
Taiwan						
Kuosheng-2 *** (#)	985			1,776,357	83.49	275,055,132
Maanshan-1	980	730,046	100.13	3,463,925	97.53	269,080,597
Maanshan-2	980	460,568	63.17	2,574,414	72.49	270,347,334
Total. Taiwan	**2,945**	**1,190,614**		**7,814,696**		
UK						
Hartlepool-1 (#)	650	NA				70,334,636
Hartlepool-2 (#)	650	NA				71,864,291
Heysham A-1 (#)	670	NA				72,157,250
Heysham A-2 (#)	670	NA				69,837,433
Heysham B-1 (#)	677	NA				70,921,020
Heysham B-2 (#)	677	NA				68,308,101
Sizewell B-1 (#)	1,250	NA				83,984,432
Torness-1 (#)	657	NA				70,826,321
Torness-2 (#)	662	NA				66,214,304
Total. UK	**6,563**					
Ukraine (Only plant level data provided divided evenly across each unit; Lifetime only from March 1993.)						
Khmelnitski-1 (#)	1,000	NA				118,877,006
Khmelnitski-2 (#)	1,000	NA				45,852,430
Rovno-1 (#)	420	NA				44,628,203
Rovno-2 (#)	415	NA				50,573,544
Rovno-3 (#)	1,000	NA				106,706,950
Rovno-4 (#)	1,000	NA				38,746,346
South Ukraine-1 (#)	1,000	NA				113,630,925
South Ukraine-2 (#)	1,000	NA				106,703,625
South Ukraine-3 (#)	1,000	NA				117,592,263
Zaporozhe-1 (#)	1,000	NA				109,265,174
Zaporozhe-2 (#)	1,000	NA				116,630,991
Zaporozhe-3 (#)	1,000	NA				115,126,945
Zaporozhe-4 (#)	1,000	NA				118,808,702
Zaporozhe-5 (#)	1,000	NA				122,277,328
Zaporozhe-6 (#)	1,000	NA				107,493,762

Nuclear Electricity Generation (continued)

COUNTRY: Plant	Capacity MW gross	MWH Gross in May	Capacity Factor May	Total MWH Gross in 2023	Capacity Factor 2023	Lifetime Total MWh gross
Total. Ukraine	13,835					
US						
Arkansas Nuclear I-1	903	651,772	97.01	3,144,672	96.12	280,983,765
Arkansas Nuclear I-2	1,065	199,479	25.18	2,724,860	70.62	293,607,457
Beaver Valley-1 *	1,011	(n)				235,084,423
Beaver Valley-2 *	1,008	(n)				198,645,194
Braidwood-1 *	1,320	(n)				249,695,083
Braidwood-2 *	1,295	(n)				250,306,191
Browns Ferry-1	1,310	829,672	85.13	4,418,961	93.11	205,260,371
Browns Ferry-2	1,310	948,846	97.35	3,533,456	74.45	337,555,246
Browns Ferry-3	1,310	919,415	94.33	4,140,023	87.23	297,792,251
Brunswick-1 (#)	998	NA				245,587,351
Brunswick-2 (#)	980	NA				243,797,166
Byron-1 *	1,268	(n)				264,821,799
Byron-2 *	1,241	(n)				256,358,743
Callaway	1,279	666,313	70.03	4,280,910	92.40	355,011,057
Calvert Cliffs-1 *	890	(n)				196,635,720
Calvert Cliffs-2 *	880	(n)				190,321,283
Catawba-1 (#)	1,305	NA				305,600,860
Catawba-2 (#)	1,305	NA				298,523,262
Clinton *	1,098	(n)				
Columbia	1,207	103,617	11.54	3,366,823	76.99	304,667,322
Comanche Peak-1 (#)	1,250	(a)		3,656,442	101.60	312,240,445
Comanche Peak-2 (#)	1,241	(a)		3,374,857	94.46	287,025,434
Cook-1 *	1,131	(n)				
Cook-2 *	1,231	(n)				
Cooper *	836	(n)				222,347,275
Davis-Besse *	971	(n)				223,155,382
Diablo Canyon-1 (#)	1,197	NA				295,669,711
Diablo Canyon-2 (#)	1,197	NA				291,715,718
Dresden-2 *	925	(n)				240,262,053
Dresden-3 *	920	(n)				231,638,789
Farley-1 (#)	918	NA				249,543,559
Farley-2 (#)	928	NA				235,899,351
Fermi-2	1,205	884,973	98.71	4,343,796	99.50	272,378,198
FitzPatrick *	849	(n)				229,730,953
Ginna *	597	(n)				172,106,861
Grand Gulf-1	1,498	1,079,225	96.83	5,353,679	98.64	362,012,046
Hatch-1 (#)	911	NA				242,630,197
Hatch-2 (#)	921	NA				228,120,616
Hope Creek *	1,250	(n)				
LaSalle-1 *	1,207	(n)				243,048,645
LaSalle-2 *	1,207	(n)				236,465,949
Limerick-1 *	1,246	(n)				263,002,965
Limerick-2 *	1,246	(n)				240,444,220
McGuire-1 (#)	1,305	NA				313,045,524
McGuire-2 (#)	1,305	NA				313,342,751
Millstone-2	918	0	0.00	1,989,003	59.84	268,648,066
Millstone-3	1,276	900,101	94.81	4,567,439	98.80	320,580,075
Monticello	691	258,120	50.19	1,743,488	69.61	221,903,922
Nine Mile Point-1 *	640	(n)				
Nine Mile Point-2 *	1,362	(n)				
North Anna-1	998	758,294	102.13	3,706,546	102.51	316,562,277
North Anna-2	994	759,813	102.74	3,713,922	103.13	309,097,050
Oconee-1 (#)	934	NA				284,412,196
Oconee-2 (#)	934	NA				287,867,739
Oconee-3 (#)	934	NA				284,805,481
Palo Verde-1	1,402	1,041,630	99.86	4,804,631	94.59	360,002,409
Palo Verde-2	1,406	260,572	24.91	3,456,887	67.86	366,412,130
Palo Verde-3	1,405	1,034,712	98.99	5,069,286	99.59	358,525,763

Nuclear Electricity Generation (continued)

COUNTRY: Plant	Capacity MW gross	MWH Gross in May	Capacity Factor May	Total MWH Gross in 2023	Capacity Factor 2023	Lifetime Total MWh gross
Peach Bottom-2 *	1,375	(n)				350,550,584
Peach Bottom-3 *	1,375	(n)				347,293,090
Perry *	1,319	(n)				263,657,668
Point Beach-1 *	640	(n)				
Point Beach-2 *	640	(n)				
Prairie Island-1 *	590	(n)				
Prairie Island-2 *	585	(n)				
Quad Cities-1 *	994	(n)				
Quad Cities-2 *	994	(n)				
River Bend	992	0	0.00	760,036	21.15	271,648,210
Robinson-2 (#)	840	NA				241,606,346
Salem-1 *	1,254	(n)				
Salem-2 *	1,232	(n)				
Seabrook *	1,296	(n)				
Sequoyah-1	1,186	895,420	101.48	4,391,398	102.20	333,966,912
Sequoyah-2	1,181	880,352	100.19	3,412,386	79.75	333,436,421
Shearon Harris (#)	1,037	NA				234,943,263
South Texas-1 (#)	1,312	(a)		2,800,696	74.15	344,992,566
South Texas-2 (#)	1,312	(a)		3,964,484	104.96	337,858,616
St. Lucie-1 *	1,078	(n)				
St. Lucie-2 *	1,135	(n)				
Summer (#)	1,006	NA				261,018,249
Surry-1	880	671,088	102.50	3,284,885	103.03	294,200,654
Surry-2	880	0	0.00	2,360,390	74.03	293,066,896
Susquehanna-1 *	1,330	(n)				
Susquehanna-2 *	1,330	(n)				
Turkey Point-3 *	885	(n)				
Turkey Point-4 *	885	(n)				
Vogtle-1 (#)	1,205	NA				276,627,641
Vogtle-2 (#)	1,205	NA				259,752,321
Waterford-3	1,222	904,267	99.46	4,244,276	95.87	334,717,923
Watts Bar-1	1,210	489,959	54.43	3,498,449	79.80	253,341,997
Watts Bar-2	1,240	912,140	98.87	4,504,158	100.26	57,422,673
Wolf Creek (#)	1,249	NA				310,745,204
Total. US	**101,262**	**16,049,780**		**104,610,839**		

Nuclear Electricity Generation for May 2023

COUNTRY: Plant	Capacity MW net	MWh net in May	Capacity factor May	Total MWh net in 2023	Capacity factor 2023
Beaver Valley-1 (#)	963	(b)		2,016,459	96.99
Beaver Valley-2 (#)	960	(b)		1,992,813	96.15
Braidwood-1 (#)	1,268	(b)		2,634,412	96.23
Braidwood-2 (#)	1,241	(b)		2,548,401	95.11
Byron-1 (#)	1,213	(b)		2,002,529	76.47
Byron-2 (#)	1,186	(b)		2,535,216	98.98
Calvert Cliffs-1 (#)	845	(b)		1,964,794	107.70
Calvert Cliffs-2 (#)	845	(b)		1,446,737	79.30
Clinton (#)	1,062	(b)		2,196,017	95.78
Cook-1 (#)	1,084	(b)		2,343,929	100.15
Cook-2 (#)	1,212	(b)		2,594,350	99.15
Cooper (#)	815	(b)		1,728,737	98.25
Davis-Besse (#)	908	(b)		1,979,762	100.99
Dresden-2 (#)	894	(b)		2,017,556	104.53
Dresden-3 (#)	879	(b)		1,971,781	103.90
FitzPatrick (#)	816	(b)		1,835,548	104.19
Ginna (#)	585	(b)		1,250,989	99.05
Hope Creek (#)	1,237	(b)		2,644,726	99.03
LaSalle-1 (#)	1,178	(b)		2,535,688	99.70
LaSalle-2 (#)	1,178	(b)		1,761,186	69.25
Limerick-1 (#)	1,205	(b)		2,515,780	96.70
Limerick-2 (#)	1,205	(b)		2,239,648	86.09
Nine Mile Point-1 (#)	613	(b)		938,678	70.93
Nine Mile Point-2 (#)	1,300	(b)		2,769,828	98.69
Peach Bottom-2 (#)	1,330	(b)		2,885,764	100.50
Peach Bottom-3 (#)	1,331	(b)		2,886,008	100.43
Perry (#)	1,268	(b)		772,220	28.21
Point Beach-1 (#)	615	(b)		1,293,140	97.39
Point Beach-2 (#)	615	(b)		975,172	73.44
Prairie Island-1 (#)	557	(b)		1,203,368	100.07
Prairie Island-2 (#)	557	(b)		1,206,244	100.31
Quad Cities-1 (#)	964	(b)		1,706,441	81.99
Quad Cities-2 (#)	957	(b)		2,001,993	96.86
Salem-1 (#)	1,169	(b)		2,555,171	101.24
Salem-2 (#)	1,181	(b)		2,442,221	95.78
Seabrook (#)	1,248	(b)		2,690,683	99.86
St. Lucie-1 (#)	1,062	(b)		2,155,376	94.00
St. Lucie-2 (#)	1,074	(b)		1,448,236	62.46
Susquehanna-1 (#)	1,287	(b)		2,750,331	98.98
Susquehanna-2 (#)	1,287	(b)		2,027,383	72.96
Turkey Point-3 (#)	844	(b)		1,871,007	102.68
Turkey Point-4 (#)	844	(b)		1,893,370	103.91
Total US	**42,883**			**85,229,692**	

Footnotes:
* Capacity factor calculated using DER Net MW Rating
** Unit came online during the year
*** Unit was shut down during the year
(a) One-month data missing
(b) Two-months data missing
(c) Three-months data missing
(d) Four-months data missing
(e) Five-months data missing
(f) Six-months data missing
(#) Yearly generation totals calculated based on existing generation data
(n) Only net and time being provided quarterly, see Net Generation Chart
NA Data not currently available

Nuclear Electricity Grid Generation for May 2023

The following data is grid generation collected by S&P Global Platts based on information from France s grid operator RTE. It represents net output from individual French reactors.

COUNTRY: Plant	Capacity MW net	MWh grid in May	Capacity factor May	Total MWh grid in 2023	Capacity factor 2023
Belleville-1 (#)	1,310	941,629	96.74	4,521,053	95.26
Belleville-2 (#)	1,310	787,424	80.9	4,169,471	87.85
Blayais-1 (#)	910	0	0	0	0
Blayais-2 (#)	910	529,776	78.35	3,119,375	94.61
Blayais-3 (#)	910	676,494	100.05	2,989,098	90.66
Blayais-4 (#)	910	0	0	695,356	21.09
Bugey-2 (#)	910	651,549	96.36	3,150,909	95.57
Bugey-3 (#)	910	622,435	92.06	2,992,997	90.78
Bugey-4 (#)	880	621,821	95.1	2,665,754	83.61
Bugey-5 (#)	880	99,456	15.21	2,404,838	75.43
Cattenom-1 (#)	1,300	574206	59.45	2899538	61.56
Cattenom-2 (#)	1,300	0	0	1,753,425	37.23
Cattenom-3 (#)	1,300	923017	95.56	1220413	25.91
Cattenom-4 (#)	1,300	820686.5	84.97	4269246.5	90.64
Chinon-B1 (#)	905	0	0	578,969	17.66
Chinon-B2 (#)	905	644,989	95.92	2,969,226	90.56
Chinon-B3 (#)	905	15,359	2.28	2,358,668	71.94
Chinon-B4 (#)	905	433251.5	64.43	1,499,302	45.73
Chooz-B1 (#)	1,500	602273.5	54.04	602273.5	11.08
Chooz-B2 (#)	1,500	1093874	98.15	1553001.5	28.58
Civaux-1 (#)	1,495	812755.5	73.17	3742222	69.09
Civaux-2 (#)	1,495	1060339.5	95.46	1288746	23.79
Cruas-1 (#)	915	326,925	48.09	2,752,658	83.04
Cruas-2 (#)	915	637350	93.75	2975734	89.76
Cruas-3 (#)	915	660,019	97.08	3,191,964	96.29
Cruas-4 (#)	915	541,041	79.58	3,060,568	92.32
Dampierre-1 (#)	890	0	0	972,107	30.15
Dampierre-2 (#)	890	597960.5	90.43	2837392.5	88
Dampierre-3 (#)	890	644069.5	97.4	3063234.5	95
Dampierre-4 (#)	890	480,127	72.61	2,614,239	81.07
Fessenheim-1 (#)	880	0	0	0	0
Fessenheim-2 (#)	880	0	0	0	0
Flamanville-1 (#)	1,330	0	0	0	0
Flamanville-2 (#)	1,330	801569	81.11	4284063	88.91
Golfech-1 (#)	1,310	0	0	0	0
Golfech-2 (#)	1,310	0	0	2,290,638	48.26
Gravelines-B1 (#)	910	0	0	776,724	23.56
Gravelines-B2 (#)	910	674,307	99.73	3,197,002	96.97
Gravelines-B3 (#)	910	614463	90.88	2932052	88.93
Gravelines-B4 (#)	910	626123.5	92.6	2419128.5	73.38
Gravelines-C5 (#)	910	667,565	98.73	3,075,017	93.27
Gravelines-C6 (#)	910	0	0	2,138,699	64.87
Nogent-1 (#)	1,310	930,240	95.57	4,339,259	91.43
Nogent-2 (#)	1,310	0	0	2,763,089	58.22
Paluel-1 (#)	1,330	73541	7.44	1,136,172	23.58
Paluel-2 (#)	1,330	918,264	92.92	3,758,546	78
Paluel-3 (#)	1,330	0	0	3,369,343	69.92
Paluel-4 (#)	1,330	892150.5	90.28	3,082,914	63.98
Penly-1 (#)	1,330	0	0	0	0
Penly-2 (#)	1,330	0	0	0	0
St.Alban/St.Maurice-1 (#)	1,335	0	0	1,448,097	29.94
St.Alban/St.Maurice-2 (#)	1,335	945912	95.36	4485100.5	92.73
St.Laurent-des-Eaux B1 (#)	915	626,604	92.17	2,926,854	88.29
St.Laurent-des-Eaux B2 (#)	915	0	0	326274	9.84
Tricastin-1 (#)	915	501,002	73.69	2,693,758	81.26
Tricastin-2 (#)	915	454,473	66.85	2,992,394	90.27
Tricastin-3 (#)	915	653,756	96.16	3,160,543	95.34
Tricastin-4 (#)	915	0	0	1,757,870	53.03
Total France	**63,130**	**25,178,798**		**132,265,316**	