



NUCLEONICS WEEK

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US Senate bill would fund nuclear energy programs at \$950 million

Senate appropriators approved a \$35.4 billion energy and water funding bill May 21 that would allocate \$950.1 million, \$14 million above the House funding, for DOE's nuclear energy programs in fiscal 2016.

The Senate Appropriations Committee endorsed nuclear power in the bill report, calling it "critical to our national security, economy, and way of life." Power reactors provide more than 20% of the electricity used in the US and 60% of the country's "emissions-

free electricity," the report said.

Included in the nuclear energy allocation for fiscal 2016, which begins October 1, is \$62.5 million for DOE's cost-share program for small modular reactor licensing technical support. The Senate funding matches the House level and is \$8 million more than the program received in fiscal 2015. The DOE program is aimed at obtaining NRC design certification and licensing of an SMR design.

Also in the nuclear energy allocation

is roughly \$43.2 million for DOE's new cost-share program aimed at operating existing US power reactors for 80 years, up from the current 40-year original licenses and 20-year renewals sought or obtained by almost all units.

The allocation is higher than the \$40 million in the energy and water funding bill the House passed May 1.

The Senate bill report called funding for this program a "priority," saying the "most cost effective way for the United

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French energy bill cutting nuclear energy use adopted in lower house

The National Assembly, France's lower house of parliament, approved May 26 by 306 votes to 217 the energy transition bill proposed by the government that would reduce the country's use of nuclear energy and boost use of renewables in its place.

The bill, sponsored by the current Socialist government, establishes goals for the country's energy policy, namely: a reduction in the share of nuclear energy in power production to

50% by 2025, an increase in the share of electricity from renewable energy to 40%, a 50% reduction in final energy consumption by 2050, and a 40% reduction from 1990 greenhouse gas emissions levels by 2030. It would also seek to reduce fossil fuel consumption by 30% from 2012 levels by 2030.

It will now be reviewed by the Senate once more before a final vote by the National Assembly, expected either this summer or fall. Under procedures

established for the legislation, the lower house has final say on the language.

The Senate — controlled by the UMP, the main center-right opposition party — had amended some of the targets, notably removing the 2025 deadline for the reduction in the share of nuclear energy. It had also increased the cap on nuclear capacity to 64.9 GW from the current capacity of 63.2 GW.

However, the lower house restored

(continued on page 12)

CAP1400 construction will begin this year: officials

Construction of China's first demonstration CAP1400 power reactor in Shandong province is set to start this year, and the unit is expected to connect to the national grid in 2019, industry officials and executives said.

"The Shidaowan-1 nuclear unit has already passed national approval of its basic design, and is ripe to start construction this year," Zhang Huazhu, the chairman of the Nuclear Energy Association said at a briefing May 18.

Speaking at a separate conference

on May 15, Wang Binghua, chairman of the State Nuclear Power Technology Company, or Snptc, said Shidaowan-1 is targeted to be connected to the country's grid sometime in 2019, according to a statement by the Nuclear Energy Association May 19.

The CAP1400 design has very significant safety, technological, economic and environmental features, Wang said.

The CAP1400 is a Chinese derivative of Westinghouse's AP1000 reactor, with the unit's generating capacity boosted

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from 1,100 MW to about 1,400 MW. China gained the right to build the AP1000 inside the country as part of an agreement to purchase four units from Westinghouse, and is allowed to export design variants of 1,400 MW and above.

The CAP1400 technology could also boost the export of China's nuclear technology, Wang said. The governments of China and Turkey are negotiating to start the construction of a CAP1400 unit in 2013, and aim to enter operation in 2023, Wang said in the statement.

On April 9, Wang visited the site of the future CAP1400 unit and urged the company make sufficient preparations of Shidaowan-1 in order to pour the first nuclear concrete, project operator the State Nuclear Power Demonstration Plant Co., or Snpdp, said in a statement April 13.

Snpdp was formed in December 2009 by Snpctc and China Huaneng Group as a 55%-45% joint venture to build and operate CAP1400 units and future larger-capacity CAP1700 units, according to statements by the Snpdp.

The company is currently seeking to get the final approvals needed from regulators to begin construction, Wang said in the statement.

More than 80% of the components for the first two CAP1400s will be made in China, Snpctc said last year.

China approved the construction of two CAP1400 demonstration units in Shidaowan in March 2013. In January 2014, the National Energy Administration approved the basic design of the CAP1400, Snpctc said.

Shidaowan-1 was scheduled to be operational in

April 2019, while another demonstration CAP1400 unit, Shidaowan-2, was scheduled to see first concrete poured in August 2015 and be operational in October 2019.

Despite the schedule, the two units still need final government confirmation on the date for the start of construction.

"China's nuclear approval process is now back to normal" following a suspension in the wake of the Fukushima I accident, NEA's Huazhu said May 18.

He said China will approve two to three more projects this year, so that a total of eight to 10 units will be approved to start construction in 2015.

China aims to expand its installed nuclear capacity to 58 GW by 2020, and the country has over 30 GW of capacity under construction, the State Council said in an energy action plan November 19.

China is likely to miss its nuclear power capacity targets of 200 GW by 2030 because some of its planned and proposed projects might be delayed or canceled, energy industry consulting company Wood Mackenzie said in an outlook note in April 2014.

Sun Qin, the chairman of state-owned China National Nuclear Corp., said last year that China's current pace of reactor construction is not enough to meet the stated goal of expanding installed nuclear capacity to 58 GW by 2020 and the country will need to start constructing units more rapidly in order to meet that goal.

NEA's Zhang said China is still hoping to fulfill the 58-GW target for 2020, as more new units are being approved.

— Hua Wen, Beijing



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Davis-Besse future depends on Ohio PUC action, FirstEnergy says

FirstEnergy said the future of its Davis-Besse reactor is not assured should the Public Utilities Commission of Ohio reject the company's proposed rate plan in a hearing scheduled to begin June 15.

The company has said the plan, which would initially mean higher monthly bills for ratepayers, will ultimately save customers billions of dollars. But critics have contended the plan will cost customers rather than save them money (NW, 5 Feb, 5).

Company spokesman Doug Colafella said in a May 21 interview that the plan "is vital to securing" the future of the 971-MW Davis-Besse unit. When asked if the reactor's future would be in doubt should the PUC reject the rate plan, Colafella said: "I think that's fair."

FirstEnergy has proposed an electric security plan that would keep distribution rates frozen from June 1, 2016, through May 31, 2019, and includes a 15-year power purchase agreement that is projected to result in saving customers about \$2 billion, Colafella said in a January 28 interview. Distribution is one of the three main components of retail power bills, along with transmission and generation.

But Matthew Kahal, an independent consultant for the Office of the Ohio Consumers' Counsel, a state agency, has said in written testimony the FirstEnergy plan would actually cost customers \$3.1 billion to \$3.2 billion over the 15 years. Kahal testified before the PUC for both the counsel's office and The Northeast Ohio Public Energy Council.

In addition, Kenneth Rose, another consultant who testified for the agency, said in testimony late last year the plan essentially "would amount to a bail-out funded by the customers of the Utility" for Davis-Besse and the company's Sammis coal plant.

Dan Sawmiller, a spokesman for the Sierra Club's Ohio Beyond Coal Campaign, said in a May 26 interview: "This plan is a bailout of an old, dirty coal and nuclear plant. Plain and simple."

The hearing was originally scheduled to begin last February but was postponed by the commission. Colafella said in a May 26 interview that FirstEnergy expects the hearing to last a month to six weeks and it anticipates a commission decision sometime in the fourth quarter of this year.

Colafella said that under its plan the FirstEnergy-owned utilities in Ohio would buy the power from FirstEnergy Solutions, the unregulated generating company that owns Davis-Besse, Sammis, and portions of two coal plants located along the Ohio River. The FirstEnergy utilities would then sell the power into the PJM Interconnection electricity market, he said.

Should the FirstEnergy utilities make a profit, customers would receive a credit on their bills; if not, customers would pay more each month for their power. PJM is a regional transmission organization covering all or parts of 13 states and the District of Columbia.

FirstEnergy Solutions would receive a fixed contract price for the power reflecting operating costs plus a profit margin, Colafella said.

FirstEnergy projects that rates will increase in each of the first three years of the agreement, Colafella said, but that starting in year four rates will begin to go down. Colafella said that current low power prices, driven largely by low natural gas prices, led to FirstEnergy's projection of rate increases during the first three years of the agreement.

The average residential bill is about \$98 a month, Colafella said, and projections are for increases of about \$3.50 a month the first year, \$2.20 a month the second year, and 22 cents a month the third year before the trend reverses in the fourth year and continues through the 15th year of the agreement.

Colafella said Davis-Besse provides energy diversity in Ohio and its continued operation would help buffer the impact of the US Environmental Protection Agency putting in place regulations to reduce carbon emitting energy sources, specifically coal plants.

— Michael McAuliffe, Washington

Chugoku Electric pushing for restart and new reactors: executive

Japanese utility Chugoku Electric Power Co. will push ahead with its plan to build a new nuclear generating station, according to a company executive, even as analysts said the government is reluctant to do so amid public concern about the safety of nuclear energy in the country.

"The government will secure a certain amount of nuclear power generation," Takafumi Shigeto, executive officer and general manager of Chugoku Electric's Tokyo office, said in an interview May 13. Given that, he added, the utility is "on track" to pursue the construction of new nuclear reactors in the future.

Chugoku Electric aims to build two new ABWRs, Kaminoseki-1 and -2, in Yamaguchi Prefecture in western Japan, Shigeto said. Each unit would have capacity of 1,373 MW. The plan has been stalled for years following the Fukushima accident.

In April, the Ministry of Economy, Trade and Industry, or METI, unveiled a draft plan for its 2030 electricity mix, in which nuclear power would account for 20%-22% of Japan's total electricity output.

METI said that in order for nuclear power to comprise over 20% of Japan's energy mix in 15 years, the operating lifetimes of some of the country's existing reactors would have to be extended. The plan does not include the construction of new nuclear units, however.

All of Japan's nuclear units are currently shut following the March 2011 accident at Fukushima I.

"We are not assuming that new reactors will be built" before 2030, although an extension of an operating life of the existing nuclear units should be expected, Kyoji Yoshino,

director-general at METI's energy agency, said at a news briefing April 28.

Two industry analysts said this week they think that the government is reluctant to embark on the building of new reactors because of public concerns about the safety of nuclear power following the 2011 Fukushima I accident. While some local governments welcome a restart of nuclear units or the building of new ones, some groups of citizens have taken utilities to court to oppose to a revival of their nuclear businesses.

"Many people are still concerned about nuclear safety in the face of the expected restart of some reactors, so the government may not go straight to a new-build," Ken Koyama, managing director and chief economist at the Institute of Energy Economics of Japan and a member of METI's panel formed to discuss the 2030 electricity mix, said in an interview May 25. The construction of a new unit "could be a next issue [for the government] to discuss after a restart performs well," he added.

Chugoku Electric's move to potentially build the Kaminoseki nuclear power plant would follow its plan to start the almost-completed 1,373-MW ABWR, Shimane-3, and restart its idled 820-MW BWR Shimane-2, which is undergoing a safety review by Japan's Nuclear Authority, or NRA.

"We are seeking to pass a review for [the restart of] Shimane-2, then we will make full efforts to start Shimane-3," Shigeto said. "And, we will also make an effort to fulfill the Kaminoseki plan."

'Recover trust' first?

One industry official said he was concerned, however, that it is premature to embark on the construction of a new nuclear power plant in the aftermath of the Fukushima accident.

"At present, when the restart of reactors is in process, the building of new units is too early to discuss. Such discussion should not start until after some reactors resume safe operations and recover trust" from the public, Takuya Hattori, president of the Japan Atomic Industrial Forum, an industry trade group, said at a news briefing May 15.

Hattori emphasized that he was speaking in a personal capacity.

There is no law to prevent a new reactor from being built in Japan. A power company can seek approval for the construction of a new reactor from NRA by following procedures similar to those for a restart application, according to the regulator.

To build Kaminoseki-1 and -2, Chugoku Electric is attempting to obtain approval from the municipal government where the units will be located to reclaim 140,000 square meters of land from the ocean for a 510,000-square-meter plant site, Daisuke Nakada, assistant manager of the utility's Tokyo office, said in an interview May 13.

On May 18, the Yamaguchi prefectural government received a safety plan for the Kaminoseki nuclear landfill project from the utility, Tsutomu Akitsu, a spokesman at

the local government's engineering department for the Kaminoseki project, said in an interview May 18. The municipal government will assess the landfill application and will determine whether to approve it for an undetermined timeframe, he added.

In addition, Chugoku Electric said that it applied May 18 to the local government to extend the completion date for the landfill construction to June 2018 from October 2015.

The town of Kaminoseki is welcoming to the idea of the new nuclear project. With a decreasing and aging population as well as a sluggish fishing industry, the town, which includes an island and is largely surrounded by the sea, is seeking a new source of tax revenue. "We are a small town and our survival could depend on nuclear power," Masakazu Hashimoto, a spokesman for the town's government, said in an interview May 18.

Chugoku Electric, like other utilities, needs to soon restart its reactors, as the company is finding it harder to continue cutting costs in order to maintain profits. For the current fiscal year through March 2016, it plans to reduce costs by Yen 28 billion (\$233 million), well below the Yen 74 million in cost reductions in the last fiscal year, Nakada said. He added that these reductions were being achieved by delaying repair and maintenance work.

Shimane-3 is currently at the final stage of the construction, with completion scheduled by March 2016, Yuji Furukawa, deputy general manager of the utility's Tokyo office, said in an interview on May 20. At a news briefing on April 17, however, Tomohide Karita, president of Chugoku Electric, did not specify the timeframe for applying to the NRA for permission to start up the new reactor, only saying that he will go ahead when regulatory approval for Shimane-2 is in sight.

Karita did say, however, that he believes that the NRA's safety review process on Shimane-2 "has not hit the half way [point] yet." The Shimane-2 safety review has been underway at NRA since December 2013.

— Yuzo Yamaguchi, Tokyo

Report into UK plutonium stockpile delivered to DECC: officials

A new report into the three credible reuse options for the UK's stockpile of plutonium from spent fuel reprocessing was delivered by the state-owned Nuclear Decommissioning Agency, or NDA, to the Department of Energy and Climate Change, or DECC, just weeks prior to the recent UK general election, according to two nuclear industry officials.

Alistair Evans, a spokesman for the Nuclear Industry Association UK, who has studied the issue of the country's used plutonium stockpile, said that the 220-page report had gone to DECC and was being handled by the security team there.

Evans noted that previously, DECC's office for nuclear development had been dealing with the plutonium stockpile

issue, and that the change to have it handled by a security group was positive as it indicates that DECC “feels the issue needs to be dealt with, it needs to be sorted.”

A DECC spokeswoman said last week the final report identifying the plutonium disposition option chosen by the NDA has yet to be completed.

A UK government report issued in January 2014 by the NDA cited GE Hitachi Nuclear Energy's Prism sodium-cooled fast reactor technology as being one of three “credible” options for reusing the UK plutonium stockpile, which now totals about 140 metric tons.

The plutonium is from a mix of early UK civilian and military reactors and is held at the Sellafield site in northern England.

The government's other two credible reuse options for the plutonium are use in a Candu Energy heavy-water reactor design and its current preferred option of reuse as mixed-oxide, or MOX, fuel in light-water reactors.

Evans said that the new report, designed as a step toward making a final decision on plutonium disposition, contained full cost estimates for the three options, but he noted that the report likely would not be released publicly due to the commercial sensitivity of those estimates.

NDA spokeswoman Deborah Ward said in an email May 21 that “the NDA's position on the plutonium stockpile remains unchanged since our last update in 2014.”

She added that “further technical studies on the three options are ongoing and these will support the Government's future policy development. A report will be published in due course, however any commercial figures relating to these options would be confidential.”

Alice Andrewartha, a DECC spokeswoman based in London, said in an email May 22 that “we expect NDA to submit its final report to DECC in the coming months. We cannot discuss the contents of the report until it has been submitted.”

David Powell, a European vice president at GE Hitachi, speaking in an interview on May 21, confirmed that the report had been submitted, but said that the contents of the report were a matter for the NDA to discuss.

Powell said his company continued to work very closely with the NDA on the potential development of the Prism reactor as a solution to the UK's used plutonium stockpile.

He said that GE Hitachi “was ready to get on with it” if the UK government asked the company to proceed with the development of Prism, noting that it “typically took five years” to develop a nuclear facility.

Powell said that GE Hitachi met local stakeholders at Sellafield and held a supply chain event in the UK county of Cumbria, where Sellafield is located, associated with the Prism reactor.

Powell said, if asked to proceed by the UK government, GE Hitachi envisaged providing two Prism reactors with a combined capacity of around 622 MW.

Candu Energy has “engaged with NDA for several years” Katherine Ward, a company spokeswoman, said in an email May 21. “Recently, we provided to them the sufficient level

of detail to address technical gaps in knowledge and provided a level of costing detail to allow a pre-procurement review of our Canmox proposal.”

Candu has said that in the Canmox proposal an Enhanced Candu 6 reactor could be operated with mixed-oxide fuel fabricated from plutonium and uranium. Existing Candu reactors have previously operated with MOX fuel, Candu said.

The Candu website describes the company's Canmox technology as “including the most recent safety and technical advances.” It notes that the “enhanced Candu 6 is the latest model in Candu Energy's family of Generation III 700 MWe class nuclear power plants, with traditional, mixed oxide and advanced fuel capabilities.”

Ward also said that, if chosen, the time frame for the development of the company's Canmox technology was “largely dependent on any decision to procure and the procurement process undertaken.”

Ward added that “if the program were to start at an early date, the development period would last until 2019-20 when Financial Close would occur. Site preparation and construction would begin, with the first reactor achieving commercial operation in 2026.”

— Oliver Adelman, London

Safety upgrades should not be politically driven: Fortum manager

Safety improvements at nuclear plants should not be made for “political” reasons, and for older reactors, the best applicable technology should be used rather than the best available technology, a manager with Finnish nuclear operator Fortum said at the Nuclear Safety 2015 conference in Stockholm May 20.

The conference was organized by consulting and conference-organizing company Informa.

After the Fukushima I accident in 2011, for instance, “all of the focus was on external events,” including the new European Union nuclear safety directive, Peter Tuominen, Fortum's vice president for nuclear safety assurance, said.

“If you look at the directive, you get the feeling that nuclear safety is only about handling external events. That's not the case,” he said. “Safety is a long-term process. Political safety improvements are not good safety improvements because they can jeopardize [doing] the really important safety improvements.”

In addition, Tuominen said that safety improvements to older reactors should be those applicable to the units, not necessarily the latest available technology.

Using the latest technology, he said, could make improvements too difficult for operators to implement, he said.

“We have to make sure we don't create a situation for the operator where it's so difficult [to upgrade safety] that we don't do anything. If we make it too difficult for ourselves

then we don't make safety improvements."

Tuominen said that nuclear plant owners also have to continue focusing on safety despite low electricity prices in the Nordic countries and high nuclear power taxes and fees in Sweden.

"It's wrong to say that nuclear safety doesn't have to do with cost control. It's wrong to say that nuclear safety can cost whatever. But it also cannot be so that when the market price is low, we start having a discussion about whether to make safety improvements," he said.

Mats Ladeborn, head of fleet development for Vattenfall, also spoke at the conference, saying that the value of safety improvements "should correlate to the cost."

In April, Vattenfall announced it wants to permanently shut Ringhals-1 and -2 earlier than planned because they are not profitable and it is uneconomic to make new safety improvements required by the Swedish Radiation Safety Authority.

Originally, Vattenfall had planned to shut both reactors around 2025, but it now wants to shut Ringhals-1 in 2018 and Ringhals-2 in 2020.

The 916-MW Ringhals-1 started commercial operation in 1976. Ringhals-2, at 910 MW, began operating in 1975.

They are Vattenfall's oldest reactors. E.On owns a minority stake in the units and must agree to the shutdown decision or they cannot be closed.

Ladeborn said Ringhals's board will be meeting before the end of May but that he does not expect a decision from E.On by then.

Alexander Lindqvist, Vattenfall's manager for operation and maintenance development, said at the conference that just a few years ago, the company looked at six different scenarios for operating its reactors and the most likely was that all seven reactors would be run for 60 years.

But he said that scenario left "little margin for political or other risks for Ringhals-1 and -2." Vattenfall subsequently decided to run the units for 50 years each, before deciding most recently on an earlier shutdown.

Lindqvist added that "the long-term need for investment is a clouded crystal ball. Projects cost a little bit too much. We are doing something wrong with our [project] model."

— *Ariane Sains, Stockholm*

EIA sees natural gas, renewable, nuclear gains from EPA rule

Switching generation from coal to natural gas-fired capacity is projected to be the "predominant compliance strategy" in the early years of the Environmental Protection Agency's Clean Power Plan, with an expected surge in renewable use and possible gains for new nuclear energy capacity depending on the exact language of the final rule, the US Energy Information Administration said in a report released May 22.

Starting in the middle of the next decade, EIA said,

renewables will play an increasing role in helping states achieve compliance with the rule, with energy efficiency programs playing "a moderate role in compliance" compared to natural gas and renewables. The report found increased coal retirements under the Clean Power Plan compared to a base case in EIA's 2015 annual energy outlook. Retirements of coal plants between 2014 and 2040 rose from 40 GW in the base case to 90 GW under the proposed rule, EIA said.

The report provides some optimism for the deployment of new nuclear capacity under a scenario where future nuclear generation "receives the same treatment as new renewable generation in compliance calculations." EIA said it was unclear what treatment would be accorded under the EPA plan to nuclear generation because of the complexity of language in proposed rules and the possibility the treatment would change in the final rule expected this summer.

Nuclear capacity in EIA's base case would increase slightly from current levels to 102 GW in 2030 and 105 GW in 2040, the report said. However, in the scenario where nuclear energy is afforded the same benefits as renewables under the EPA rule, capacity in 2030 would be 113 GW and rise to 121 GW in 2040, EIA said.

As proposed, the Clean Power Plan aims to cut power sector CO2 emissions to 30% below 2005 levels by 2030, with interim reduction targets in 2020. The rule empowers states to craft compliance plans using four main "building blocks" for reducing the carbon intensity of power generation, including increased dispatch of gas-fired power and greater use of renewable and energy efficiency resources.

The proposed rule treats five nuclear units already under construction as if they had been built, meaning bringing those units online would not count towards reducing carbon intensity targets. It is not clear whether future nuclear units would be counted in the planned intensity reduction in a final EPA rule, EIA said in the report.

A range of power industry groups and state officials have argued that existing, under-construction and future nuclear power should all be credited towards reducing a state's carbon intensity of generation. A final version of the rule is expected late this summer, government officials have said.

While most of the base case coal retirements would occur before 2017, the report noted that "nearly all" of the coal retirements under the Clean Power Plan would occur by 2020. "Retirements of inefficient units fueled by natural gas or oil, generally involving primary steam cycles, are also projected to rise," EIA said.

EIA projected that electricity production from natural gas-fired plants will increase from 1,117 billion kWh in the base case to 1,382 billion kWh in 2020 under the Clean Power Plan, with production climbing from 1,371 billion kWh under the base case to 1,429 billion kWh in 2030. Production from wind and solar is also projected to increase significantly under the proposed rule, with wind production climbing from the reference level of 245 billion kWh to 562 billion kWh under the EPA rule in 2030 and solar climbing from 71 billion kWh in the base case to 148 billion kWh under the EPA rule in 2030.

The report projected that nuclear generation would be 804 billion kWh in 2020 with or without the EPA rule in any form. However, the report said in its base case that nuclear generation in 2030 would be 808 billion kWh, while it would be 900 billion kWh if EPA promulgated the rule in its final form with treatment of new nuclear plants similar to treatment of renewables.

Nuclear generation in the base case in 2040 would be 833 billion kWh, while it would be even lower in that year, at 813 billion kWh, if the EPA rule is issued as proposed. Nuclear output would reach 962 billion kWh in 2040 if the EPA rule incorporated the changes in treatment of nuclear energy, EIA said.

Generating capacity from natural gas and oil, however, may not grow significantly under the rule, according to the report. EIA found that gas- and oil-fired capacity would grow from 482 GW in the reference case to 490 GW in 2020, but fall from 519 GW to 518 GW in 2030.

'Significant' renewable growth seen

The report found that the proposed rule "significantly increases projected renewable capacity additions in all cases," with wind and solar in particular seeing additions. Wind capacity is projected to climb in 2030 to 192 GW compared to the reference level of 87 GW, with solar reaching 76 GW as opposed to the 39 GW in 2030 in the base case.

The report as well projected that the Clean Power Plan "does not significantly move natural gas prices with the exception of an initial impact expected during the first 2-3 years after the start of implementation."

Henry Hub spot prices for natural gas in 2020 would rise from \$4.88/MMBtu in the reference case to \$5.83/MMBtu under the proposed rule, increasing to \$5.86/MMBtu in 2030 compared to \$5.69/MMBtu in the base case.

EIA found that coal production and steam coal prices would be lower compared with reference case in the early years following Clean Power Plan implementation, with US production falling 20% in 2020 and 32% in 2025 compared to the base case.

"All major coal-producing regions (West, Interior, and Appalachia) experience negative production impacts in 2020," the report said. However, EIA noted that higher natural gas prices and other factors are projected to allow higher utilization rates for coal-fired plants in the later years, which would allow coal production to increase in 2040 but still be below the reference case.

The report comes with a number of caveats, including that the analysis does not "consider any potential health or environmental benefits from reducing CO₂" and that the rule itself could change "in material ways" between proposed and final iterations. The report also noted that states' approaches to compliance "may have different characteristics" than the "regional compliance patterns" offered in the report.

EPA spokeswoman Liz Purchia noted these and other caveats in an email May 22, saying that "the agency will be reviewing the assessment as we work to develop the final

rule." She also said that compliance choices by states and utilities will in many respects "determine the impacts of the program," while also noting the significant health and environmental benefits of reducing CO₂ emissions.

"EPA looks forward to continuing the conversation with DOE, and with FERC, as we work to finalize and implement the Clean Power Plan," Purchia said.

— Bobby McMahon, Washington

Czech nuclear plan does not address finance issues, minister says

A national energy plan that would expand the use of nuclear power in the Czech Republic, drafted by the country's Ministry of Industry and Trade and due to be adopted by the government at the start of June, will not deal with the issue of financing new reactors, Deputy Industry and Trade Minister Pavel Solc said in an interview May 26.

Speaking on the sidelines of the two-day European Nuclear Energy Forum in Prague, organized by the governments of the Czech Republic and Slovakia, Solc said there was still no political agreement on the financing issue.

A national energy plan adopted earlier this month envisages an expansion of nuclear power in the country by 2040, with 46-58% of the country's electricity planned to be produced by nuclear plants by then, compared with around a third of its electricity produced by nuclear power now.

A decision on how to finance construction of new nuclear power plants could be delayed for a few years to see how electricity prices develop and whether government support for electricity prices or other guarantees for new nuclear plants would be necessary, he said.

The National Action Plan for the Development of Nuclear Power is scheduled to be debated by government ministers June 3.

Solc said the ministry envisaged a rebound in electricity prices which could mean that state support for new nuclear plants might not be necessary. "The next three years will be crucial," Solc said. "A first step could be a recovery of electricity prices to around Eur50/MWh by around 2019. It could then advance in the longer term to around Eur70-90/MWh," Solc said.

Off-peak spot power prices May 27 were Eur29.83/MWh, according to Platts data.

The minister, who bears the main responsibility for Czech energy policy, said that the main impetus for rising European electricity prices would be the anticipated retirement of thousands of megawatts of capacity over the next few years, especially in Germany and Poland, which could support higher prices.

Solc added that decisions on financing nuclear power plants could be easily postponed for five years or so. The Czech Republic would probably need to select a technology supplier for the first new plant between 2020 and 2022, and 2025 would probably be the latest date for a decision on

whether to construct a first new reactor, he said.

Minister of Industry and Trade Jan Mladek said at the Prague forum May 26 that the most likely scenario for construction of new nuclear reactors in the country is for a first reactor to be built at state-controlled electricity company's CEZ's Dukovany site with a second to follow at its Temelin facility. Dukovany's four operational nuclear reactors are likely to be phased out by 2035, Mladek said.

The development plan for nuclear power will urge CEZ, which is almost 70% state owned, to push ahead with preparations for a new reactor at both the Dukovany and Temelin sites, Solc said. It will also establish a committee to advise on developments, he added.

The broader national energy plan already gives CEZ an assurance that future governments will not change policy over the importance of nuclear power in the country, meaning the risk of making investments based on this commitment to nuclear energy are low, he said.

The financing of new nuclear power plants has been a major issue for the current center-left government after it decided in April 2014 not to provide CEZ price guarantees for new nuclear units. CEZ immediately afterwards cancelled its ongoing tender for two new reactors at its Temelin site.

Czech Minister of Finance Andrej Babis said during a visit to the Dukovany plant May 23 that CEZ could alone cover the investment costs of constructing a new reactor at the site, given its low level of indebtedness compared with other European power companies.

CEZ's spokesman Ladislav Kiriz said in an email response to questions May 26 that a return on investment is still a key issue for CEZ's shareholders and that would probably require further discussion.

— *Chris Johnstone, Prague*

Terrestrial Energy sees avenue for MSR deployment in Canada

Terrestrial Energy is planning to license and deploy a molten-salt reactor in Canada that its designers say offers improved safety features over LWRs and will be competitive with fossil fuels in operating costs, CEO Simon Irish said in an interview May 21.

The design provides an improved safety profile over existing LWR reactors, which in turn improves its economics to the point where it can compete with coal and natural gas generation, Irish said.

Terrestrial Energy was formed in 2013 to develop and deploy a new molten salt reactor design in Canada. Irish said the Canadian regulatory system, with a process based on showing a design meets certain principles of safe operation, offers a more predictable path to licensing than that in the US, where safety requirements are more prescriptive and rulemaking of uncertain length is required to certify a design.

The company hopes to build a reactor of about 80 MW

thermal in Canada, beginning the first phase of the process to receive vendor design approval from the Canadian Nuclear Safety Commission by early next year, Irish said. A commercial unit could be operating around 2024 or 2025, he said.

Terrestrial's design for an integral molten salt reactor, or IMSR, is derived from a research reactor, the Molten Salt Reactor Experiment, that operated at Oak Ridge National Laboratory in the 1960s, Terrestrial said in an article by Irish and company Chief Technology Officer David LeBlanc that was published in an American Nuclear Society publication in December. Additional development of the design came from a follow-up reactor that was designed but never built by ORNL, Irish said.

One of the key designers from the team that worked on both designs is part of the Terrestrial team, Irish said.

Molten salt reactors use uranium, and sometimes other fissile materials, dissolved in a salt to serve as both coolant and fuel.

The fuel salt mixture circulates through a core containing a moderator composed of graphite elements, and exchanges heat with another cooling circuit containing molten salt without nuclear fuel. A separate circuit produces steam used to spin the turbine and generator.

The Terrestrial IMSR is not designed to breed plutonium, Irish said.

The design provides economic benefits that stem from the superior safety profile compared with LWRs, Irish said.

The IMSR can handle decay heat generated after shutdown more easily than can LWRs, he said. The hot fuel is in liquid form, so it can cool by convection, he said.

The need for decay heat removal and for active systems to cool the reactor means LWRs need secondary and sometimes tertiary containment structures, which also raises costs, Irish said. Solid fuel results in much more "complicated decay heat management" which in turn results in regulatory requirements for redundant safety systems, he said. The additional complexity results in added costs, he said.

In addition, the IMSR provides large fuel savings, Irish said. There is no solid fuel to be fabricated, and the liquid fuel provides a far more efficient burn of uranium, he said. The IMSR will require one sixth of the low-enriched uranium and generate one sixth of the plutonium of an LWR producing equivalent energy, Irish said.

One challenge of all molten salt designs is the lifetime of materials exposed to the corrosive salts and fission products in the primary fuel salt loop. Reactor pressure vessels and heat exchangers have been found to be subject to corrosion, and graphite elements experience expansion and cracking, especially when a higher-density core is employed, Terrestrial said in the article it provided.

Terrestrial's solution is to design the IMSR with a permanently sealed core unit, containing the reactor vessel, heat exchangers and some pumps, that has a seven-year design life. This would allow for a compact, high-density core and a 3.6-meter (11.8-foot) diameter core unit that could be delivered by flatbed truck, Terrestrial said in the article.

At the end of a seven-year operating period, the core unit would be disconnected from coolant lines, which would be connected to a new unit in an adjacent containment silo, Terrestrial said. The first core unit could remain in place for seven years in preparation for the removal of fuel salt and components at a later date.

Terrestrial has said it is working with nuclear laboratories, including Canadian Nuclear Laboratories and ORNL, on research that will assist in advancing the design to the licensing phase. Terrestrial said in statement May 26 that it had contracted with the Dalton Nuclear Institute at the University of Manchester in the UK for similar services.

Another company, ThorCon Power, has said it is working separately on a molten salt reactor design in which modules would operate for a specified period before being swapped out. ThorCon told NRC officials in April that it is considering seeking a license to build a prototype for an MSR but that it also is considering deploying an unfueled test version to validate some aspects of the technology prior to licensing (Inside NRC, 20 Apr, 1).

ThorCon is proposing a 250-MW design that also borrows from ORNL's Molten Salt Reactor Experiment design. ThorCon said it intends to use techniques used in ship construction to manufacture a canister containing a cauldron for the fuel salt, a pump, and a primary heat exchanger. Secondary and tertiary cooling loops would contain different salts, and a fourth loop would contain water and steam.

The reactor could be built at a site adjacent to Energy Northwest's Columbia plant in Washington state, ThorCon officials said.

Transatomic Power said in February it had raised \$2.5 million to continue development of its design for a molten salt reactor. The company has said it hopes to build a 20-MW demonstration reactor by 2020, possibly at Idaho National Laboratory.

— William Freebairn, Washington

Jaczko renews criticism of nuclear energy during Taiwan visit

Former NRC chairman Gregory Jaczko said the Fukushima I accident is "far from over" and called for a phasing out of nuclear power in favor of alternatives during a three-day visit to Taiwan last week.

Jaczko visited Taiwan from May 21-23 at the invitation of the "Taiwan-Japan No Nukes Research Association" and the Humanistic Education Foundation.

During his stay in Taiwan, the former NRC chairman held a news conference May 21 and a public lecture at the Legislative Yuan, Taiwan's parliament, May 23, where he reiterated his position that nuclear power is unsafe.

On May 22, Jaczko met with opposition Democratic Progressive Party, or DPP, chairwoman and presidential candidate Tsai Ing-wen at the DPP headquarters in Taipei City and met ruling Chinese Nationalist Party chairman and New

Taipei City Mayor Chu Li-lun the following day at his office.

New Taipei City, which surrounds the capital of Taipei City, is home to two of the country's three operating nuclear power plants and Lungmen, the fourth plant. Work was halted and the first new unit "sealed" to preserve components following street protests and a hunger strike by a leading opponent in 2014.

Both Tsai and Chu advocate a phase-out of Taiwan's three nuclear plants by 2025 by not extending their operating licenses.

Jaczko said the reactor meltdowns and hydrogen explosions at Fukushima I in 2011 "overturned many long-held assumptions," especially that severe nuclear power plant accidents could not happen.

Jaczko related that "there was much activity and ample opportunity to try to prevent the serious accidents that ultimately occurred in these reactors, but the impacts from the earthquake and tsunami and bad design combined to create this tragedy."

Jaczko said that "the reactor crisis at Fukushima Daiichi is over, but the accident is still continuing."

"This accident will not be over until the reactor fuel is removed and disposed of, the reactor units are decontaminated and decommissioned, the site is fully cleaned, the surrounding communities are restored and those who suffer receive suitable compensation," he said. "Decades will be needed before these objectives can be achieved and some of these tasks may never be accomplished," Jaczko said.

"Right now the biggest challenge is dealing with the steady supply of contaminated water, which continues to leak into groundwater and the sea around the reactors," he said.

Jaczko added that the human cost also continues to rise as over 100,000 people are still evacuees and cannot return to their homes.

The Fukushima I accident had exposed technical, legal and regulatory weaknesses, including insufficient regulatory independence, inadequate emergency systems, but said that the most important lesson was that "nuclear power plant accidents are unavoidable."

Jaczko said that main weakness in the "bad design" of light water reactors was their potential inability to cope with decay heat.

Nuclear plants "need special mechanical systems to cool reactors and remove the high levels of heat that still exist even after they are turned off in normal or emergency conditions," said Jaczko, who emphasized that "all these systems are human made and mechanical and will therefore eventually fail."

However, Jaczko said that the definitions of "safe" with regard to nuclear power are often different among ordinary people and participants in the nuclear power industry.

"Most people believe 'safe' means a freedom of occurrence of injury, danger or loss, but to the nuclear power industry, 'safe' means that the chance of a severe accident is very low but always possible," Jaczko said.

Jaczko said that after Fukushima, "safety must mean that

no accident can ever require evacuation of any people who are outside of the plant or cause injury to the surrounding community or society.”

Most nuclear power plants operating do not meet that safety standard, he said.

Jaczko said that “nuclear power can be replaced by alternative technologies that meet carbon reduction goals and can be safe and reliable forms of electricity and are not significantly more expensive and are often cheaper.”

“I think the best solution is to replace nuclear power with alternative technologies, especially near populated areas,” Jaczko said.

According to the IAEA, there are 67 reactors now under construction worldwide, 24 in China and nine in Russia.

New designs behind schedule

Jaczko also questioned whether new nuclear power plant designs being introduced in the United States and China would prove to be more reliable or economical.

“Four reactors with new designs are now being built, but are behind schedule and \$1.5 billion over budget despite promises that they would be completed on time and on budget,” Jaczko said.

Within 15 years, most nuclear units in the US will be nearing the end of their licenses and will be preparing for eventual shutdown, he said.

Jaczko noted that the only country which is making a large scale push to build nuclear power capacity is China, but he added that “this may be a little distorting as the PRC [China] is building lots of capacity in everything, including solar and wind.”

“The advantages of nuclear power are short term but the disadvantage of spent fuel lasts for generations upon generations,” he said.

Jaczko related that few countries had found long-term ways to deal with this problem.

Jaczko noted that finding a repository in Taiwan, which has a high degree of seismic risk, “is a challenging problem,” but also said that he saw “no advantages” to sending spent fuel offshore for reprocessing.

In response to a question after his May 23 lecture, Jaczko also stated that the clause in the US-Taiwan nuclear cooperation agreement signed last year permitting Taiwan to send spent fuel out of the country for reprocessing “does not imply that the United States approves of such reprocessing.”

Jaczko acknowledged that finding a feasible final spent fuel repository site “is challenging in Taiwan given its geology and the size of the island and therefore harder here than in the United States.”

Jaczko also suggested that countries with a small number of nuclear plants and relatively small land mass could consider “regional cooperation” in the search for final disposal repositories for spent fuel.

Jaczko said that the nuclear industry is well established in Taiwan, as in other countries, and acknowledged that “moving away from this technology is difficult.”

“However, relying on this technology creates economy

and society wide risks and responding and recovering from accidents are extremely difficult,” Jaczko said, concluding that “transition is possible but requires planning and bold leadership among government and industry.”

Teaching and lecturing

In response to a question during his May 21 news conference at the National Taiwan University Alumni Center, Jaczko said that “unsealing” Lungmen and proceeding with operation would be unwise. Jaczko said the project, which has been under construction for 16 years, is now “outdated” and unable to meet current safety standards.

Jaczko said in an interview May 22 that he is “doing some teaching and lecture tours” such as the three-day visit to Taipei and that a book on his experiences at the NRC and other observations on the Fukushima I incident and the state of the nuclear power industry is now in the final stages of editing by his publisher.

— Dennis Engbarth, Taipei

FPL gets six months of additional water for Turkey Point site

Florida Power & Light can access up to 100 million gallons of excess storm water per day for six months from a canal feeding Biscayne Bay starting June 1 to help reduce the temperature and salinity of the closed-loop cooling canal system serving its two Turkey Point nuclear units in Miami-Dade County, FPL said in a May 26 email.

The emergency order approved by the South Florida Water Management District on May 19 “is effective through November,” FPL spokesman Greg Brostowicz said in the email.

FPL had asked the district to approve water withdrawals for June-through-November periods in both 2015 and 2016, and has asked the district to reconsider its decision to allow withdrawals in only the June-through-November period this year.

Brostowicz said that “a combination of multiple factors led to the current condition of the cooling canal system,” including several years of lower-than-normal rainfall and warm weather that caused more evaporation, and above-normal salinity level. Algae blooms “exacerbated the situation by retaining heat in the system, perpetuating the evaporative losses and increasing salinity.”

Last August, the South Florida Water Management District “approved an order allowing us to add excess storm water from the L-31 canal to the Turkey Point cooling canal systems — a key part of our plan” to address the cooling canal systems’ temperature and salinity issues, the FPL spokesman said. The L-31 canal is the body of water feeding Biscayne Bay from which the removal was approved.

“Last summer, we saw that the addition of excess water from the L-31 canal significantly improved conditions in the system in a relatively short period of time despite below

average rainfall," Brostowicz said. "Knowing this, we are taking proactive action this summer to ensure we can access the excess water as early as possible — June 1 — and maintain grid reliability while we execute our plan to improve the health of the canal system over the longer term."

FPL has a three-part strategy for addressing canal system issues over the longer term. The first involves adding low-salinity water to the canals "to reduce the salt content of the canal system water to a level that is comparable with [nearby] Biscayne Bay," said Brostowicz.

The second element involves removing sediment buildup from the canals, and the third calls for upgrading equipment to increase the plant's cooling capability. "In addition to improving the overall health of the canal system, to ensure that we continue to meet all regulatory requirements, we are adding additional heat exchangers and water chillers to the plant's system," Brostowicz said. "These improvements provide additional capability to cool equipment that is used for power production."

In a related move, the NRC last August approved an amendment to FPL's license that revises the ultimate heat sink water temperature limit for the cooling canal's supply water to 104 degrees F from the original 100 F.

FPL's Brostowicz said in the May 26 email that the utility's request for South Florida Water Management District approval to withdraw water from the L-31 canal and its longer-term strategy "are intended to help ensure that we can continue to operate within our NRC technical specifications."

Asked if FPL would have needed to shut the units or ramp down their operation if the utility had not been granted the emergency order, Brostowicz replied, "No. We are working proactively now to help ensure that we do not approach the NRC requirements later this summer when electric demand and temperatures are at their peak."

FPL depends on Turkey Point-3 and -4 to provide base-load power to customers in South Florida and has said that reducing their output or taking them offline would threaten the reliability of electric service there. Several entities, including the Everglades Law Center, opposed FPL's plan to divert additional storm-water from the L-31 canal, asserting that the plan would harm Biscayne Bay and Biscayne National Park.

Asked about the water needs of FPL's proposed Turkey Point units 6 and 7, which could come online as soon as the mid-2020s, Brostowicz said, "The new units would not utilize the cooling canal system. Instead, the new units would rely upon reclaimed water from Miami-Dade County."

— *Housley Carr, Carversville, Pennsylvania*

Senate ... from page 1

States to maintain low-cost, carbon-free electricity is to safely extend the lives of ... existing nuclear reactors" through so-called subsequent license renewals.

It directed DOE "to continue research and development

work on the technical basis for subsequent license renewal," saying the department should focus on "materials aging and degradation, advanced instrumentation and control technologies, and component aging modeling and simulation."

Differences between the Senate and House versions of the bill would be ironed out in a House-Senate conference committee after the Senate approves its version of the bill. A vote on the bill in the Senate has not been scheduled.

Funding for DOE's fuel cycle research and development program would be \$217 million under the bill, up from \$175.8 million in the House bill and \$20 million more than the program received this fiscal year. The Senate allocation includes \$64 million for the continuation of R&D into the behavior of spent fuel during long-term storage and transport and in various geologic media, the bill report said. It also said "priority" should be given to an ongoing study of high-burnup fuel in dry storage and to research on whether spent fuel could be disposed of in existing spent fuel dry storage canisters.

Also included in the fuel cycle allocation is \$30 million for a consent-based process that DOE wants to launch by the end of the year to site spent fuel storage and disposal facilities, including a geologic repository.

Spent fuel storage

Senators Lamar Alexander, a Tennessee Republican and chairman of the Senate Appropriations Subcommittee on Energy and Water Development, and Dianne Feinstein of California, the ranking Democrat on the subcommittee, have said that resolving the nuclear waste issue is important to the future of nuclear power in the US.

"We have a huge problem in this country," Feinstein said when the full committee considered the bill May 21. "We have nowhere for this waste to go." If the US is going to have nuclear power, "we need someplace to put the waste," she said (NuclearFuel, 25 May, 6).

The Senate funding bill "broadens the contractual arrangements by which the government can acquire spent fuel storage capabilities," which now is limited to federally owned and operated interim storage facilities, the bill report said. A Senate Appropriations Committee summary of the bill said the legislation allows DOE to store spent fuel at private-sector facilities such as those under consideration in Texas and New Mexico. The bill does not contain any funding for DOE's use of private sector storage facilities but opens the door for that option.

Under existing law, DOE can site and operate an interim spent fuel storage facility only after NRC has issued a license for DOE to construct and operate a high-level nuclear waste repository at Yucca Mountain, Nevada. DOE's dismantlement in 2010 of the repository project at Yucca Mountain, the planned site for a spent fuel disposal facility, left the country without a path forward for the 74,000 metric tons of spent fuel now stored in the US. That inventory grows at a rate of 2,000 mt a year.

The report said the bill also includes a pilot program for the consolidated storage of utility spent fuel, "pending

enactment of comprehensive legislation." No funding, however, was included in the bill for that effort.

Unlike the House bill, the Senate bill does not contain any funding for a Yucca Mountain repository. The House bill does not fund interim storage but would provide a total of \$175 million to DOE and NRC for work related to the Yucca Mountain repository project.

Alexander and Feinstein have included the pilot program language in the energy appropriations bill the last three years, according to the committee summary of the measure.

They and Senators Lisa Murkowski, an Alaska Republican and chairman of the Senate Energy and Natural Resources Committee, and Maria Cantwell of Washington, the ranking Democrat on the energy committee, introduced a bipartisan bill March 24 that would establish a new national strategy on nuclear waste. The Nuclear Waste Administration Act, S. 854, would move the nuclear waste program out of DOE to a separate entity that would use a consent-based process to site one or more spent fuel interim storage facilities and one or more repositories.

Murkowski, who is a member of the appropriations committee, said May 21 that her committee will hold a hearing in June on that nuclear waste bill.

Advanced fuels

Also in the fuel cycle allocation is \$60.1 million for the development of advanced reactor fuels. The bill report told DOE to continue development of accident-tolerant fuels and to have a commercial fuel assembly ready for testing by 2022. It directed DOE to work with industry, universities and other organizations to develop a "roadmap" for the commercialization of these technologies, "including new Silicon carbide based ceramic material" and "to share the outcome of this consultation with the Committee."

Lawmakers expressed concern in the bill report, without elaborating, that DOE's ongoing work on accident-tolerant fuels would not produce "meaningful reductions in the consequences of unexpected severe accidents" at nuclear units and provided \$12 million for an industry-led cost-share program on accident-tolerant fuels and \$3 million for the continuation of competitively awarded projects on the development of ceramic cladding for reactor fuel.

Lawmakers told DOE to provide within 30 days of the bill's enactment a plan to the committee for the "development of accident tolerant fuels leading to in-reactor testing and utilization."

Elsewhere in the bill, Centrus Energy would receive \$50 million, the same amount as the House allocation, to maintain centrifuges and facilities associated with the American Centrifuge Plant that Centrus wants to build in Piketon, Ohio (NW, 30 Apr, 1). Under the bill, DOE could reprogram an additional \$50 million for the ACP, subject to committee guidelines. Centrus, formerly USEC, is the only US uranium enricher using US-origin enrichment technology. By treaty, the US can only use uranium for national security purposes that was enriched by US-origin technology.

The bill also would fund construction of DOE's

Mixed Oxide Fuel Fabrication facility in South Carolina at \$345 million, compared to \$331.2 million in the House bill. Feinstein criticized the project, whose current \$47 billion projected cost is up from the original estimate of \$3.5 billion. The facility would dispose of 34 mt of surplus weapons-usable plutonium by using it to fabricate mixed-oxide fuel for power reactors. "We need to find an alternative," she said.

— Elaine Hiruo, *Washington*

France ... from page 1

the deadline and a lower cap.

After the vote, Energy Minister Segolene Royal said the law was "the most advanced energy legislation" aimed at tackling global climate change, making France "an exemplary model before the Paris climate conference." Paris will be the host to the United Nations Climate Conference, or COP 21, to be held from November 30 to December 11.

The legislation was rejected by the UMP, represented by deputy Julien Aubert, who criticized it as "an approximate copy of the German model," referring to Germany's policy to increase the share of renewables while phasing out nuclear power.

The UMP deputy went on to criticize the potential costs associated with the targeted reduction in the nuclear share of France's electricity generation, estimating that it would cost Eur5 billion to close the two reactors at Fessenheim, citing a bipartisan parliamentary report release September 2014. The Eur5 billion figure includes compensation payments for early closure but not replacement power costs.

EDF has been given permission to operate the Fessenheim reactors for a further ten years and has therefore made significant investments in the plants to conform to safety guidelines.

In the run-up to presidential elections in 2012, President Francois Hollande pledged to shut EDF's 1,800-MW Fessenheim plant, but more recently Royal has indicated alternative plans would be considered.

With the nuclear capacity cap back in the legislation, this means EDF must retire 1,650 MW of nuclear capacity when EDF's Flamanville-3 EPR starts commercial operations, currently forecast in 2017.

UMP's Aubert added that replacing the 20 GW of nuclear capacity expected to shut under the law "would require 35 GW of wind power and 70 GW of solar power; or [respectively] 20,000 turbines and 650 square kilometers (650 square miles) of solar cells, in addition to additional investments in thermal plants." Citing a report by the power sector association UFE, published June 2014, he put the total investment cost at Eur190 billion (\$207 billion).

He also criticized the schedule, estimating that it would force the closure of 24 reactors in the next ten years. "Everyone knows that it is impossible to close 24 reactors in the next 10 years," Aubert said.

France, through EDF, the state-controlled electric utility,

operates 58 nuclear reactors. According to RTE, the national electricity regulator, nuclear energy provided 415.9 TWh of electricity to the grid in 2014, representing 77% of total net electricity production.

100% renewable power possible, says study

A report published in April by the French Environment and Energy Management Agency, a government agency reporting to the Ministry of Energy known as Ademe, suggested costs to switch to a 100% renewable-powered grid would not be much higher than the cost to switch to a 40% renewable-powered grid.

The report concludes that it would cost Eur119/MWh to power France using 100% renewables, compared with Eur117/MWh with a 40% renewable share.

The May 26 day-ahead French electricity price was Eur32.75/MWh, while year-ahead baseload power was Eur38.25/MWh.

The report highlights that to maintain the annual costs of electricity at Eur119/MWh under the reference case, storage technologies would need to be introduced to the grid to

supplement renewables, the report said.

Onshore wind power is assumed to reach a levelized cost of electricity of Eur65/MWh, while solar PV is assumed to reach Eur60/MWh. LCOE is a standard form to calculate production costs across different technologies using a discount rate and over a given period of time.

With regard to nuclear power, Ademe said that nuclear costs are "set so as to reach a [LCOE] target of Eur80/MWh with an 80% capacity factor," by 2050

The consumption forecast under the Ademe scenario would necessitate "important efforts" to improve energy efficiency with an assumption of 422 TWh saved by 2050, which would entail lower electricity consumption than 2014.

In the reference case, the bulk of the future electricity generation would be met by wind power (63%), followed by solar (17%) and hydro power (13%).

Several storage technologies are assumed to be used in the reference case, with inter-seasonal storage carried out by "power to gas," which uses electricity to produce methane, which can be stored easily.

— Benjamin Leveau, London