Written Comment Form
Hawai'i Interisland Renewable Energy Program: Wind

Comments must be postmarked by March 1, 2011.

Thank you for participating in the public meeting process for the Hawai'i Interisland Renewable Energy Program: Wind - Environmental Impact Statement. We invite you to use this form to provide your public comments for consideration as we prepare for the Draft Environmental Impact Statement (DEIS).

When providing your comments, please be as specific as possible. Also, please write clearly so we can read your comments. If you complete this form at today's meeting, you can drop it in the comment box provided. If you do not wish to complete your comments during this meeting, this form is designed so you can take it home, fill it out, and easily mail it in (see the other side for directions). Your input into this scoping process is needed and appreciated. If you wish to be notified of the availability of the Draft EIS, please check here [ ] and provide your name, mailing address and/or e-mail address below.

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COMMENTS

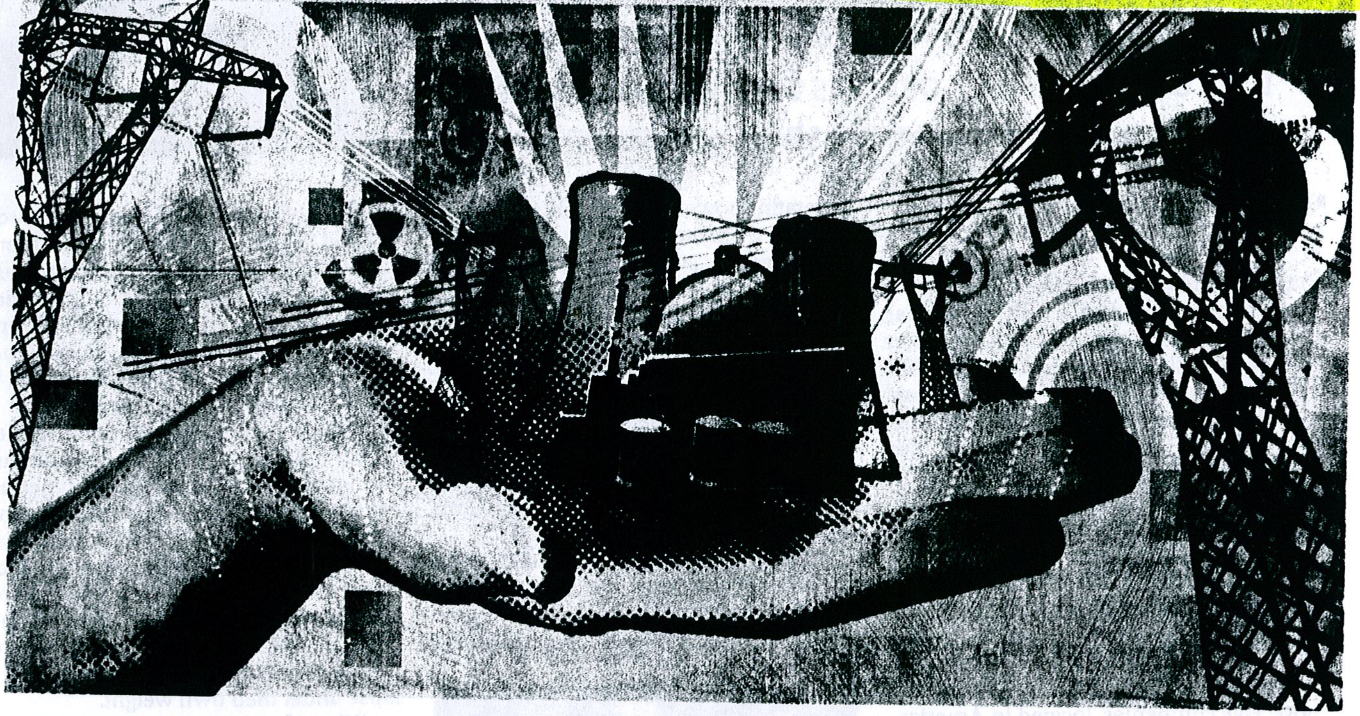
BECAUSE THE SUBMARINE CABLE WILL COST ABOUT $1,000,000,000 IT IS VERY IMPORTANT THAT ALL PRACTICAL OPTIONS BE EVALUATED. FIRST, WIND ENERGY IS NOT ~~DISPATCHABLE~~ DISPATCHABLE, THIS MEANS THAT IT CANNOT REPLACE OLD OIL FIRED STEAM UNITS THAT MUST BE RETAINED TO KEEP THE LIGHTS DURING THE ANNUAL SYSTEM PEAK WHICH OCCURS AFTER SUNSET ON "LIGHT WIND" EVENINGS. IF WIND IS TO REPLACE EXISTING STEAM UNITS, A LARGE PUMP STORAGE PLANT MUST BE INSTALLED. (AND EVALUATED)

AT THIS COST LEVEL THE TWO FOLLOWING FIRM BASE LOAD GENERATING UNITS MUST BE EVALUATED. "OTEC" (OCEAN THERMAL ENERGY CONVERSION) SYSTEM AND ALSO THE NEW B+W 125 MW UNDERGROUND NUCLEAR POWER PLANT. NUCLEAR POWER HAS PROVED ITSELF TO BE THE SAFEST WAY TO GENERATE FIRM BASE LOAD POWER IN THE U.S. THUS IT MUST BE CONSIDERED.

THE LEGISLATURE EXPECTS NUCLEAR TO BE CONSIDERED BECAUSE A DOZEN MEMBERS OF THE HAWAII STATE HOUSE OF REPRESENTATIVES HAVE INTRODUCED HB NO. 57 AND HB NO. 62.

SEE ATTACHED ARTICLES ON SMALL NUCLEAR GENERATING UNITS. THIS 125 MW B+W NUCLEAR GENERATOR IS THE IDEAL SIZE FOR THE ISLAND OF OAHU,

The Economist Technology Quarterly December 11th 2010



Thinking small

Nuclear power: Combining several small reactors based on simple, proven designs could be a better approach than building big ones

WHEN the two big nuclear reactors under construction at Flamanville in France and Olkiluoto in Finland come on stream, each will boast enough electricity-generating capacity to light up a city of 1.5m. But despite the best efforts of EDF and Areva, which are building the reactors, both are behind schedule and, at over $5 billion apiece, well over budget. With results like these, it is little wonder that the vaunted "nuclear renaissance" has failed to materialise. In fact, the number of operating reactors is in decline, spurring the nuclear-power industry to look for new approaches. Rather than relying on huge, traditional reactors costing billions, it is turning to small, inexpensive ones, many of which are based on proven designs from nuclear submarines or warships.

A global race is under way to develop small-reactor designs, says Paul Genoa of the Nuclear Energy Institute, an industry body in Washington, DC. He estimates that more than 20 countries have expressed serious interest in buying mini-reactors.

At least eight different approaches are being developed, mainly in America and Asia, by an army of 3,000 nuclear engineers, according to Ron Moleschi of SNC-Lavalin Nuclear, an engineering firm based in Montreal. Regulatory and licensing procedures are lengthy, so little will be built until around 2017, he says. But after that the industry is expected to take off. The International Atomic Energy Agency (IAEA) estimates that by 2030 at least 40 (and possibly more than 90) small reactors will be in operation. It reckons that more than half of the countries that will build nuclear plants in coming years will plump for these smaller, simpler designs.

Nuclear deliveries

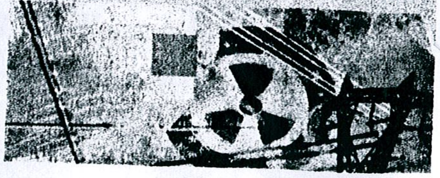
Russia is an early adopter. Rosatom, the state nuclear-energy giant, is building a floating, towable power station in a St Petersburg shipyard. The *Akademik Lomonosov*, due to set sail in 2012 for waters near Russia's far-east town of Vilyuchinsk, will be followed by at least four other floating nuclear plants for the country's Arctic regions. Such power stations are less prone to earthquakes and avoid the difficulties of erecting nuclear facilities on frozen land, which can melt, jeopardising foundations, says Vladimir Kuznetsov of the IAEA. And at a mere $550m a pop they cost a fraction of what a traditional reactor does (though they also provide less power).

Rosatom hopes its plants will appeal to energy-hungry coastal or river cities all over the world. By manufacturing in Russia, the firm sidesteps some of the regulatory controls a client country would impose on a plant built and installed on its own soil. Another selling point is Russia's willingness to bring home the nuclear waste. Demand for floating plants may also help Russia broaden, or at least retain, its nuclear expertise, which has suffered as engineers have gone abroad or retired.

Similar concerns are driving efforts to develop small reactors elsewhere. No new nuclear plant has come on stream in America since 1996. The industry was dealt a blow in October, when Constellation Energy, a utility, dropped a joint plan with EDF to build a large nuclear plant in Maryland. In spite of strong political support and a reported $7.5 billion in government loan guarantees, Constellation balked at the initial capital outlay. Steven Chu, America's energy secretary, sees miniaturisation as a way to revive the country's once-mighty nuclear industry.

One advantage of small reactors is their modularity. Extra units can be added to a plant over the years, incrementally boosting output as capital becomes available and electricity demand rises. NuScale, of Corvallis, Oregon, offers "scalable" nuclear plants with reactors delivered by truck. A plant with 12 reactors, each with its own electricity-generating turbine, would cost about $2.2 billion and produce roughly a third as much power as a big facility. Since large plants can cost roughly three times as much, the cost of electricity would be about the same. Moreover, a modular facility would generate revenue as soon as the first reactor is fired up, after a ▸▸

> "Engineers of small reactors stress their similarity to proven, existing designs such as those found in nuclear-powered ships and submarines."



few years of construction. A big reactor traditionally takes a decade to erect.

Hyperion Power Generation, a firm based in Santa Fe, New Mexico, is building components for what it calls a "nuclear battery". The refrigerator-sized Hyperion Power Module (HPM) reactor will shift much of the building from field to factory, where a controlled environment reduces costs. Also, fewer workers and families must be moved, at great expense, to distant building sites. HPMs would be delivered by truck with enough uranium to run for about ten years. They would be constructed in batches with interchangeable parts and cost about $100m each. And they need little human oversight to operate. "Forget huge—let's make a hand-held version of a power plant," says John Deal, the firm's boss. Five companies, located in America, Britain, Canada, China and India, have put down deposits for an HPM.

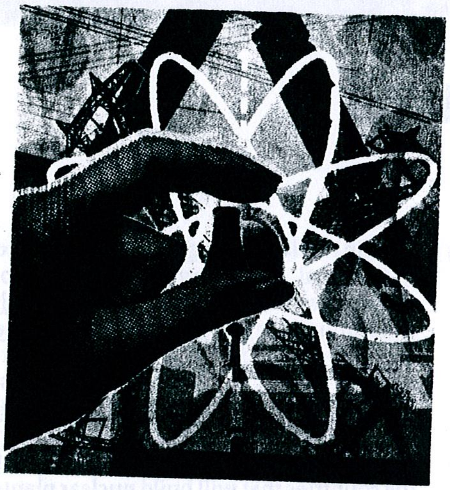
Engineers of small reactors stress their similarity to proven, existing designs such as those found in nuclear-powered ships and submarines, or, in Rosatom's case, ice-breakers. And some small-reactor designs have an important advantage over bigger reactors. Because less heat is generated, small water-cooled reactors can use simpler designs relying not on pumps, but on natural convection. And eliminating moving parts should make the new small reactors both safer and cheaper. For instance, Hyperion's HPM dispenses with elaborate valve systems by using a molten metal as a coolant because, unlike water, it doesn't need to be kept under pressure to absorb large amounts of heat.

Christofer Mowry, who heads civilian power at Babcock & Wilcox, a maker of nuclear-propulsion systems for the US Navy, says the company's small reactor offers another source of savings. Because it can use existing power-transmission lines without overloading them, the mPower can act as a "drop-in replacement" for ageing coal furnaces without the need for costly refurbishment. The Tennessee Valley Authority, America's biggest public utility, hopes to put two of the firm's reactors into an old coal plant. Five other American utilities are also considering replacing coal furnaces with nuclear reactors, according to Philip Moor of the American Nuclear Society, an industry group. He estimates that in America alone perhaps 100 old coal plants could be converted to nuclear within a decade—a trice by the industry's standards.

ALSO OIL FIRED POWER PLANTS

Not all nuclear nations have entered the fray. France has studied micro-reactors' potential in spaceship propulsion, but for generating power on Earth, big reactors are best, says Christophe Béhar, in charge of nuclear energy at the country's Atomic Energy Commission. New markets for large plants are opening up as developing countries strengthen their grids to cope with the huge amounts of power they produce. China is building two small helium-cooled reactors, but the electricity they produce will never be as cheap as that from big reactors, according to Mr Béhar. Just in case, the Chinese have also commissioned French firms to build two large nuclear plants.

In Japan, too, utilities' interest in small reactors appears scant for now. Tatsujiro Suzuki, the vice-chairman of the Atomic Energy Commission in Tokyo, hopes it will



grow. Today's broad trend to loosen government controls on electricity prices may do the trick. Utilities are more willing to make massive investments if they can accurately predict future income. As prices are allowed to fluctuate more widely, shorter-term investments for smaller reactors will become more attractive. At least one Japanese engineering giant sees promise in the market for such devices. Toshiba says its 4S ("super-safe, small and simple") reactor is capable of running for three decades without refuelling.

Small comfort

Sceptics fear that these small, cheap reactors will not be enough to revive the nuclear industry. Mycle Schneider, a nuclear-energy expert at École des Mines, an engineering school in France, who is also an adviser to Germany's environment ministry, says licensing and building small plants will take far too long to be profitable. As the costs of solar, wind and biogas power continue to fall, investors will increasingly favour household energy-producing kit and transmission technologies that let consumers sell excess production to neighbours and utilities, he says. South Africa's decision in September to abort construction of a small reactor, even though about $1.3 billion had been spent, illustrates the sort of financial risk the sector faces.

Others fret that lots of small reactors, rather than a few big ones, will be more vulnerable to a terrorist attack. Hyperion's Mr Deal insists that neither a rocket-propelled grenade nor a tank round could smash a small reactor. Small reactors can be shielded by a heavy layer of concrete and buried, in effect making them safer than big ones, whose protective concrete domes can only be so thick, lest they collapse under their own weight.

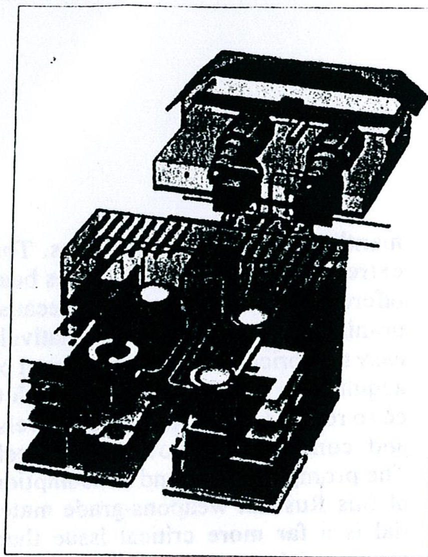
What if a rogue government tries to take advantage of an affordable reactor to acquire nuclear expertise or materials for weapons work? Henry Sokolski, a former Pentagon official who heads the Nonproliferation Policy Education Centre, a think-tank near Washington, DC, says that Western intelligence agencies have overestimated their ability to monitor the spread of nuclear equipment and know-how. If new enrichment facilities are built to supply a slew of small nuclear reactors, materials and expertise useful in bomb-making may spread as a result.

TerraPower, an American firm backed by Bill Gates, thinks it has the solution. It is working with Toshiba to design a small reactor based on a "travelling wave" design. Once kick-started with a tiny amount of enriched uranium, it would run for decades on non-enriched, depleted uranium, a widely available material. This will be possible because the nuclear reaction, eating its way through the core at the rate of about one centimetre a year, would gradually convert the depleted uranium into fissionable plutonium—in effect "breeding" high-grade fuel and then consuming it.

Mr Gates points out that nuclear power has historically been dogged by five worries: safety, proliferation, waste, cost and fuel availability. "This thing is a miracle that solves all five," he says. John Gilleland, TerraPower's boss, says that a single enrichment plant would then suffice to produce all the enriched uranium needed to spark up the world's mini-reactors.

The prospects for mini-reactors, like those for large reactors, depend on a combination of technical, commercial and regulatory factors. The stars do not seem to be aligning for large reactors. But they are no longer the only game in town. ■

Late News



Babcock & Wilcox's mPower reactor design

Alan S Lloyd
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Late News This Month:

B&W WILL SEEK APPROVAL FOR A NEW MODULAR PWR that is intended to be manufactured entirely by North American suppliers, built underground, and able to store in a containment-enclosed pool all of the spent fuel arising from its 60-year operation. The Babcock & Wilcox Company announced on June 10 that it would apply to the Nuclear Regulatory Commission in 2011 for design certification for what the company calls the mPower reactor, a 125-MWe pressurized water reactor. B&W also hopes in 2011 to "engage a commercial customer" that would apply to the NRC for a combined construction and operating license (COL) in 2012. The COL would, ideally, be issued in 2015, allowing for plant operation to begin in 2018. The announcement came during an event at Nuclear Energy Institute headquarters in Washington, D.C., where the participants included representatives from the Tennessee Valley Authority and Exelon, along with Sens. George Voinovich (R., Ohio), Lamar Alexander (R., Tenn.), and Bob Corker (R., Tenn.), and Reps. Lincoln Davis (D., Tenn.) and Zach Wamp (R., Tenn.). The Tennessee involvement has to do with a TVA–B&W letter of intent to explore the use of the Clinch River site near Oak Ridge as a lead plant site for the mPower reactor. TVA and Exelon have both expressed support for the mPower initiative, B&W said, but neither has committed to filing a COL application.

Both TVA and an Exelon predecessor, Commonwealth Edison Company, were involved in the last nuclear project at that location, the Clinch River Breeder Reactor, a liquid-metal fast-breeder reactor project spurred by the federal government through the Atomic Energy Commission but never completed. The involvement of power reactor licensees in the mPower campaign may be intended to show customer interest in the design. The NRC has been reluctant to devote resources to the certification of reactor models for which electricity providers have not sought licenses, as well as to small, "grid-appropriate" reactors.

B&W refers to the mPower design as "Generation III++" but stresses the aspects of the design that most closely fit in with the nuclear industry that exists now. The core would be a 17 × 17 array of fuel assemblies essentially the same as those used in current power reactors, only shorter. No ultraheavy forgings would be required, thus averting long-lead bottlenecks at Japan Steel Works and allowing every component to be manufactured in North America. B&W said that its existing supply chain can provide everything needed. The major departures from current practice are in the long duty cycle (five years between refuelings), the provision for pool storage of the reactor's entire 60-year buildup of spent fuel, underground construction, and low water use (makeup water for the nuclear steam supply system, but air cooling for the rest of the plant). B&W said it believes that two to six modules could operate at a typical site, providing power in increments reasonable for mid-sized or small utilities. Although the company did not give cost estimates, it said that mPower's scalability would make it competitive.

B&W had notified the NRC in an April 28 letter of its plans to apply for design certification in the first quarter of 2011. The NRC replied on May 27 that the mPower reactor design would come under the agency's Advanced Reactor Program, "which not only needs to consider licensing reviews in future fiscal years, but also the development of infrastructure related to new and different reactor technologies." B&W had asked to begin pre-licensing activities in June 2009. The NRC replied that for budgetary reasons, through September 2010 "the NRC staff will need to limit interactions with the designers of small power reactors to occasional meetings or other nonresource-intensive activities. As such, any requested work on the mPower reactor design that goes beyond these limitations will be placed on hold."

THESE 125 MW NUCLEAR GENERATING UNITS ARE AN IDEAL SIZE FOR THE HECO POWER SYSTEM SERVING THE ISLAND OF OAHU. TWO SUCH UNITS WOULD GENERATE ABOUT 25% OF OAHU'S ELECTRIC ENERGY NEEDS WITH NO GREENHOUSE GAS EMISSIONS AND WOULD SAVE ABOUT 3,000,000 BARRELS OF OIL EACH YEAR.

Mail Call

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"A Far More Critical Issue"

The article by Neil C. Livingstone in the February issue of *Sea Power* raised critical issues related to the illegal trafficking in sensitive nuclear materials that appears to be taking place in Eastern Europe and the Middle East. However, his discussion of the cargo of the *Akatsuki Maru*, the ship carrying reprocessed plutonium from France back to Japan, requires clarification with respect to the difference between "reactor-grade" and "weapons-grade" plutonium and uranium. The various grades of these two fissionable elements depend on the percentage of the "fissile" isotopes contained in a given consignment of uranium or plutonium. The following table lists the approximate U-235 or fissile content (enrichment) of the various grades of uranium:

Depleted uranium tailings	0.2%
Natural uranium	0.7%
Reactor grade (commercial fuel)	3% or 4%
Weapons-grade uranium	Over 90%

The grade or enrichment of uranium is controlled by how much of the U-238 is removed during the isotopic separation process. Fissile plutonium Pu-239 is produced as a result of uranium U-238 capturing and retaining a neutron. Pu-239 also can capture a neutron and become Pu-240, which is not fissile and is a neutron emitter. The proportion of Pu-240 is determined by how long the fuel rod remains in the reactor. This Pu-240 content determines whether or not the plutonium is suitable for weapons use. For this reason, weapons-grade plutonium was produced in dedicated production reactors like the N reactor at Hanford, where the rods remained in the reactor for relatively short periods. As a result, the Pu-240 content was kept to an absolute minimum. By comparison, the fuel rods in modern light water reactor power plants, such as those in Japan, remain in the reactor for three to five years. During this period the content of the Pu-240 can build up to as much as 30 percent. The following table indicates the various plutonium isotopes that build up in the spent fuel in commercial power plant reactors. The indicated Pu-240 concentration is typical for reactor-grade plutonium.

Pu-239	58%
Pu-240	24%
Pu-241	13%
Pu-242	5%

Because of a phenomenon called predetonation, this high Pu-240 content renders reactor-grade plutonium unsuitable for practical nuclear weapons use. However, this reactor-grade plutonium is perfectly satisfactory for enriching fresh fuel for conventional nuclear power plants and is particularly desirable for use in breeder reactors. The *Akatsuki Maru* was in fact returning the reactor-grade plutonium that had been separated from the spent fuel of Japan's nuclear power plants. The U.S. Committee of Energy Awareness estimates the Pu-240 content of the *Akatsuki Maru*'s cargo at between 21 and 22 percent. This policy of utilizing recovered plutonium from spent fuel is a spectacular example of recycling valuable resources. For example, one ton of reactor-grade plutonium should produce about the same amount of electricity as approximately 3,000,000 tons of coal or 12,000,000 barrels of oil. As noted in Mr. Livingstone's article, the critical issue is the control of weapons-grade fissionable materials. This is particularly true for highly enriched uranium. The 11 January 1993 issue of *Aviation Week and Space Technology* reports that the Russians have about 500 tons of weapons-grade uranium (and about 96 tons of weapons-grade plutonium) that will become available from dismantling their nuclear weapons. This extremely sensitive material has been offered for sale to the West. Because uranium-type bombs are relatively easy to fabricate, this uranium must be acquired as quickly as possible, diluted to reactor-grade enrichment levels, and consumed as power-plant fuel. The prompt dilution and consumption of this Russian weapons-grade material is a far more critical issue than commercial reactor-grade material being returned to Japan by the *Akatsuki Maru*.

Alan S. Lloyd
Kailua, Hawaii

Mr. Livingstone replies:

I thank Mr. Lloyd for taking the time to write. Unfortunately, I relied on newspaper articles which were incorrect in referring to the Akatsuki Maru*'s cargo; however, I should have been alert enough to draw the distinction between weapons and non-weapons grade plutonium. I am in his debt for his clear and concise explanation of the difference between the two.*
—Neil C. Livingstone.

Announcement

***Britanis/Monterey* Documentary:** The production company Au Large de L'Eden is working on an hour-long documentary for French television on the American ocean liner *Britanis* which served during World War II as a troop and weapons carrier. The company would like to interview Navy officers or crewmembers who served aboard the *Monterey* (as it was called during the war) or its sister ships *Mariposa* and *Lurline*. Anyone with information on the ship, its crew, or an existing division association may write to: Au Large de L'Eden, c/o Tele-Europe, 50 rue Croix des Petits Champs, 75002 Paris, France, or call Stephanie Mingasson at 0-11-33-1-44-58-18-52, or fax 0-11-33-1-40-15-92-25.

The Nuclear Option

Energy concerns prompt officials to eye propulsion alternatives for surface combatants

By TOM WITHINGTON, Special Correspondent

FUEL WISE THE HAWAIIAN ISLANDS ARE SHIPS AT SEA. THEY DEPEND ON OIL FOR FIRM DISPATCHABLE ELECTRIC POWER.

Renewed Focus

The use of nuclear power to propel aircraft carriers and submarines has long been standard U.S. Navy practice, but not so for other ships.

- In the past, acquisition costs and the perceived abundant supply of fossil fuels drove propulsion plant decisions for future surface ships.
- Energy sources today are far less secure and prices far more volatile.
- The increased attention to carbon footprint, cost and national security implications of importing fossil fuels have contributed to the renewed look at nuclear propulsion.

Navy Secretary Ray Mabus was forthright in his concern about the services' dependence on fossil fuels, articulating them in the Department of the Navy publication "Naval Energy: A Strategic Approach," published in October 2009.

He warned that U.S. "energy sources are not secure, we need to be more efficient in energy use. … The United States Navy is under pressure to reduce its oil consumption. Price volatility, coupled with concerns regarding the security of the nation's oil supply are prompting the force to look at alternatives to fossil fuels."

Could a renewed focus on nuclear power for surface vessels offer a solution to Mabus' challenge?

The use of nuclear power to propel aircraft carriers and submarines has long been standard U.S. Navy practice. However, nuclear power for surface combatants such as frigates, destroyers and cruisers has been less widespread.

From 1961 to 1999, the force operated several nuclear-powered cruisers, the last of which, the California-class USS *South Carolina*, left the fleet just before the turn of the last century. Apart from these cruisers, no other naval surface vessels outside of aircraft carriers have been equipped with nuclear power plants. Instead, the Navy has opted for conventional propulsion.

The reason for this, according to Tom Dougan, spokesman for the Naval Nuclear Propulsion Program Directorate in Washington, is because "acquisition costs and the perceived abundant supply of fossil fuel has driven past decisions regarding the selection of propulsion plant type for U.S. Navy surface ship design."

U.S. Rep. Gene Taylor, D-Miss., concurred, noting the U.S. Navy has not chosen nuclear propulsion for other surface vessels since the last batch of nuclear-powered cruisers entered service in the mid-1970s.

"Fuel was a heck of a lot cheaper then," said Taylor, who touted the idea of a nuclear-powered variant of the Arleigh Burke-class destroyer as the Navy's next missile cruiser several years ago. "Secondly, our nation was a lot more energy independent, and now we're importing over 60 percent of our oil, most of it coming from places that are not friendly with the United States."

In 2008, the United States imported 11.31 million barrels of oil per day, according to the "CIA World Fact Book." And U.S. oil imports often have to transit through the pirate-infested waters off the Gulf of Aden, and via maritime chokepoints such as the Strait of Hormuz, making for tempting targets.

On Oct. 6, 2002, the MV *Limburg*, a French-flagged oil tanker, was attacked by suicide bombers in a small boat. The explosion resulted in the release of 90,000 barrels of oil into the Gulf of Aden. More recently, the Japanese oil tanker *M Star* was attacked by a small explosive-laden boat, according to investigators in the United Arab Emirates, while navigating through the Strait of Hormuz Aug. 6. However, no oil leaked from the hull as a result of that explosion.

The guided-missile destroyer USS *Cole* sits pierside at Naval Station Norfolk, Va., Oct. 10, two days before the 10th anniversary of the suicide bombing of the ship that killed 17 Sailors and wounded 39 while it was refueling in the Port of Aden in Yemen. *Cole* returned to the fleet in 2002 and has deployed four times since the attack.

Navy oilers could become potentially lucrative targets in a future conflict, during which they could be attacked in order to deprive surface combatants of the fuel required to escort and protect the aircraft carrier battle groups, Taylor said.

Taylor, a member of the powerful House Armed Services Committee and chairman of its seapower and expeditionary forces subcommittee, lost his bid for re-election Nov. 2.

Oil supplies also are at risk of being disrupted as a result of fallout from a conflict that may not directly involve the United States, but which may affect areas where tankers ply their trade. Witness the disruption caused to oil distribution during the Iran-Iraq War, when the two countries performed attacks on tankers in the Persian Gulf from 1984.

Market volatility and political unrest in oil-producing nations can lead to price increases or supply disruption that threaten to further tax a U.S. defense budget already under pressure.

Dependence on fossil fuels also has tactical consequences for the Navy. Surface ships can be vulnerable to attack when they are being refueled at sea. Moreover, given the dependence that surface combatants have on fossil fuels, naval oilers can be attractive targets for an enemy.

The October 2000 suicide bomb attack on the Arleigh Burke-class destroyer USS *Cole* in Yemen, which claimed the lives of 17 Sailors during a refueling stop, underscored the reality that foreign ports where U.S. Navy ships routinely refuel also are susceptible. These factors are having an effect on U.S. Navy thinking.

"Increased attention to carbon footprint and the increased cost and national security implications of foreign-based fossil fuel supplies have contributed to the renewed look at nuclear propulsion," Dougan said.

For energy security, nuclear-powered naval vessels have a clear appeal. Unlike their diesel- or gas turbine-powered counterparts, they do not require regular refueling, effectively limiting the vessel's endurance to that of its crew. Furthermore, nuclear reactors can have a life span eclipsing that of the ships they equip, typically around 50 years. Although 30 to 40 years is more common for a submarine reactor, it still can exceed the service life of the boat.

Yet the Navy's embrace of nuclear power for surface combatants has been cautious, with the notable exception of the aircraft carrier. Nevertheless, the option of nuclear power for such vessels has not been completely disregarded.

Dougan noted that "for each new ship design the Navy considers, through an analysis of alternative options, nuclear power, hybrid electric mechanical and combined plant architecture propulsion for all future surface combatants and amphibious warfare ships. In addition, quantifiable analysis of ship warfighting, vulnerability, sustainability, energy demands and mobility effectiveness are evaluated against acquisition and life-cycle costs."

"It comes down to cost and mission requirements," according to a U.S. Navy source.

In fact, the Navy is mandated by Section 1012 of the fiscal 2008 Defense Authorization Act which states that "it is the policy of the United States to construct the major combatant vessels of the naval strike force, including all new classes of such vessels, with integrated nuclear power systems." However, the caveat is added in the same section that this will occur "unless the Secretary of Defense submits with the request a notification to Congress that the inclusion of an integrated nuclear power system in such vessel is not in the national interest."

To this end, the U.S. Navy's CG(X) Next Generation Cruiser had been earmarked to receive a nuclear power plant, although the program has been canceled.

Nuclear power for surface vessels does not come cheap. According to a 2009 paper entitled "Nuclear Marine Propulsion," written by Magdi Ragheb, an associate professor at the University of Illinois and an expert in nuclear engineering, the average naval nuclear reactor costs between $100 million for a nuclear submarine and $200 million for an aircraft carrier.

Even at the end of their lives, naval nuclear reactors still have a bill. Ragheb estimates the disposal of an Ohio-class submarine's General Electric S8G Pressurized Water Reactor can cost around $12.8 million, with the disposal of a Los Angeles-class boat's reactor costing around $10.2 million. These costs, however, must be offset against the refueling costs for a diesel- or gas turbine-powered vessel throughout its life.

The decision on which power plant will equip a surface combatant is an issue of tradeoffs. On one hand, a conventional diesel-powered warship requires a comparatively lower financial outlay.

The September Congressional Research Service (CRS) publication "Navy Nuclear-Powered Surface Ships: Background, Issues, and Options for Congress" cited a cost increase of up to $800 million to equip a surface vessel with nuclear instead of conventional power.

Based on official U.S. Navy statistics, the unit cost for a Ticonderoga-class guided-missile cruiser is around $1 billion. Should it be equipped with a nuclear power plant, that cost would almost double, to around $1.8 billion. Furthermore, nuclear power may not necessarily deliver a dramatic reduction in life-cycle costs.

The CRS report argues that the total life-cycle cost for a medium-sized surface combatant outfitted with a nuclear reactor would be the same as that for a conventionally powered surface vessel, provided that the price of oil is maintained at between $70 and $225 per barrel. However, should the oil price escalate beyond that, nuclear power could start to represent a less expensive alternative vis-à-vis life-cycle costs.

The life-cycle costs for naval nuclear reactors, however, may shrink in the future as nuclear technology advances.

"The major technological change since design of the USS *Nautilus* [the U.S. Navy's first nuclear submarine] has been the increased lifetime of reactor cores. While the USS *Nautilus* had to be refueled after two years of operation, significant research and development efforts have given the USS *Virginia*, the lead boat in the eponymous class of attack submarines, a 33-year life of ship core," said Dougan, removing the necessity of refueling and the expense that this would incur.

Dougan notes that increasing the core's life can help to reduce costs in other ways.

"A longer-life core results in less time in the shipyard, more time to perform critical missions and an overall reduction in the number of ships. These changes, combined with the increasing price of fossil fuels, make nuclear power a more attractive option. The heightened interest in reducing carbon footprints and decreasing the reliance on foreign-supplied fossil fuel add to the benefit of nuclear power," he said.

This is enhanced by the difficulty of predicting the price of oil, which may rise to such a level as to make nuclear power extremely competitive when it comes to operating costs.

Whether the U.S. Navy chooses to equip its future frigates, cruisers and destroyers with nuclear reactors will depend on financial calculations and security issues. If the price of oil suffers serious instability, and if the global oil distribution system suffers shocks in terms of terrorist actions or conflict, then it may be strategically sensible in the long run for the service to utilize this option. It will then be necessary to look closely at the potential cost savings that nuclear powered warships can offer compared to their conventionally powered counterparts. ■

This Nuclear Option Is Nuclear

The costs of fads and superstition.

BY GEORGE F. WILL

THE 25 PEOPLE killed last week in the West Virginia coal-mine explosion will soon be as forgotten by the nation as are the 362 miners who were killed in a 1907 explosion in that state, the worst mining disaster in American history. The costs of producing the coal that generates approximately half of America's electricity also include the hundreds of other miners who have suffered violent death in that dangerous profession, not to mention those who have suffered debilitating illnesses and premature death from ailments acquired toiling underground.

Which makes particularly pertinent the fact that the number of Americans killed by accidents in 55 years of generating electricity by nuclear power is: 0. That is the same number of Navy submariners and surface sailors injured during six decades of living in very close proximity to reactors.

America's 250-year supply of coal will be an important source of energy. But even people not much worried about the supposed climate damage done by carbon emissions should see the wisdom—cheaper electricity, less dependence on foreign sources of energy—of Tennessee Sen. Lamar Alexander's campaign to commit the country to building 100 more nuclear power plants in 20 years.

Today, 20 percent of America's electricity, and 69 percent of its carbon-free generation of electricity, is from nuclear plants. But it has been 30 years since America began construction on a new nuclear reactor.

France gets 80 percent of its electricity from nuclear power; China is starting construction of a new reactor every three months. Meanwhile, America, which pioneered nuclear power, is squandering money on wind power, which provides 1.3 percent of the nation's electricity: it is slurping up $30 billion of tax breaks and other subsidies amounting to $18.82 per megawatt-hour, 25 times as much per megawatt-hour as the combined subsidies for all other forms of electricity production.

Wind power involves gargantuan "energy sprawl." To produce 20 percent of America's power by wind, which the Obama administration dreamily proposes, would require 186,000 tall turbines—40 stories tall, their flashing lights can be seen for 20 miles—covering an area the size of West Virginia. The amount of electricity that would be produced by wind turbines extending the entire 2,178 miles of the Appalachian Trail can be produced by four reactors occupying four square miles of land. And birds beware: the American Bird Conservancy estimates that the existing 25,000 turbines kill between 75,000 and 275,000 birds a year. Imagine the toll that 186,000 [WIND] turbines would take.

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Solar power? It produces less than a tenth of a percent of our electricity. And panels and mirrors mean more sprawl. Biomass? It is not so green when you factor in trucks to haul the stuff to the plants that burn it. Meanwhile, demand for electricity soars. Five percent of America's electricity powers gadgets no one had 30 years ago—computers.

America's nuclear industry was a casualty of the 1979 meltdown of the Three Mile Island reactor in Pennsylvania, which was and is referred to as a "catastrophe" even though there were no measurable health effects. Chernobyl was a disaster because Russians built the reactor in a way no one builds today—without a containment vessel. *

Since the creation of the Tennessee Valley Authority, Alexander's state has played a special role in U.S. energy policy. The last commercial reactor opened in America is Watts Bar, Unit 1 in Tennessee. And, in a sense, all uses of nuclear power began in that state.

In September 1942, the federal government purchased 59,000 acres of wilderness in eastern Tennessee and built an instant city—streets, housing, schools, shops, and the world's most sophisticated scientific facilities. This was—is—Oak Ridge. Just 34 months later, a blinding flash illuminating the New Mexico desert announced the dawn of the atomic age. That is what Americans can do when motivated.

Today, a mini-Manhattan Project could find ways to recycle used nuclear fuel in a way that reduces its mass 97 percent and radioactive lifetime 98 percent. Today, Alexander says, 10 percent of America's lightbulbs are lit with electricity generated by nuclear material recycled from old Soviet weapons stocks. This is, as Alexander says, "one of the greatest swords-into-plowshares efforts in world history, although few people seem to know about it." It is a travesty that the nation that first harnessed nuclear energy has neglected it so long because of fads about supposed "green energy" and superstitions about nuclear power's dangers.

* ALSO, WITH NO PRESSURE VESSEL AND AN INFLAMABLE GRAPHITE MODERATOR.