Arguments in favour of nuclear waste storage in South Australia should not be so easily dismissed. There are valid economic and moral arguments made in the Royal Commission's interim report, writes Mike Steketee. It may be the ultimate NIMBY proposal: Australia taking the world's nuclear waste, or at least a good chunk of it, and burying it deep in the South Australian outback. Surely you would have to be out of your mind, as a government or a voter, to volunteer for such a project? Would you feel better if we were paid for it? How about $5 billion a year over 30 years and $2 billion a year for the following 40 years? They are the figures mentioned in the "tentative findings" issued this week by South Australia's Nuclear Fuel Cycle Royal Commission headed by former governor Kevin Scarce. Many would respond that no amount of money would be worth it. But as well as the economic case outlined in the report, there is a moral argument, which goes like this. We have the world's largest known uranium resources and are the world's third largest producer (after Kazakhstan and Canada) of uranium for nuclear reactors (but hopefully not for nuclear weapons, although the strict safeguards on which we insist are no guarantee). The waste from nuclear fuel from our uranium, together with that from other producers, is piling up around the world in temporary storages. Some of it is very long-lived and very dangerous.
If reprocessed, it can be turned into nuclear weapons. A less complex option is to use radioactive material to make a dirty bomb. In the age of terrorism, that is a real concern. So far not a single country has built a permanent facility to safely dispose of the waste, although two - Sweden and Finland - have ones underway. Australia has some of the most stable geological formations in the world in outback South Australia, Western Australia and the Northern Territory. That is, the earth has not moved in these regions for millions of years. They are arid and flat, meaning there also has been no groundwater movement. And they are very sparsely populated.

You can argue that countries that opt for nuclear power should bear the responsibility for dealing with the consequences, including waste. Like earthquake-prone Japan? Or Pakistan, where terrorists run riot? The nuclear waste lying around in temporary facilities is a threat to the world, including Australia. The Royal Commission will issue a final report in May and is seeking public comment on its tentative findings in the meantime. Not surprisingly, they have provoked a strong response, with Mark Diesendorf of the University of NSW describing them as "extraordinary" and a "heroic fantasy". But the report does not deserve to be dismissed so readily.

Nor does the South Australian Labor Premier, Jay Weatherill, who set up the commission, although insisting he has an open mind on the subject.

One of the tentative findings is that it would not be commercially viable to build a nuclear power plant in South Australia in the foreseeable future. However the commission says its use should not be precluded in all future circumstances - for example, if a national requirement for net zero carbon emissions by 2050 could not be met from renewable sources.

Another finding is that uranium processing, including enrichment, would not be viable in South Australia in the next decade, given a global over-supply and low prices. The exception would be if we adopted fuel leasing, under which Australia would supply processed uranium while agreeing to take back the spent fuel to ensure it is not turned into nuclear weapons.
George W Bush's administration advanced the idea of leasing and it is endorsed by the International Atomic Energy Agency as an anti-proliferation measure. The Obama administration reportedly has held preliminary talks with several countries, including Mongolia, Japan and the United Arab Emirates about leasing arrangements. The commission's third main tentative finding is that the storage and disposal of nuclear waste could deliver substantial economic benefits to South Australia. It says a permanent storage facility could be in operation by the late 2020s. Of course we are not talking about any old garbage. The report says it takes 500 years for the most radioactive elements of high level waste in the form of used nuclear fuel to decay and total isolation from the environment is needed for hundreds of thousands of years. Even low level waste requires containment and isolation from the environment for up to a few hundred years before it reaches the levels of naturally occurring background radiation. The commission believes storage and disposal of high and intermediate level waste in a South Australian location are likely to be technically feasible, though detailed investigations would be required. It argues that the state has "a unique combination of attributes which offer a safe, long-term capability for the disposal of used fuel", including geology, very low levels of seismic activity, an arid environment and a stable political, social and economic structure. Given the quantities of used fuel held by countries that are yet to find a solution for disposal, the report says the market should be big enough for a South Australian repository. It cites a "conservative baseline price" for permanent disposal of $1.75 million per tonne of high level waste and $40,000 per cubic metre of intermediate level waste. The commission argues that a project taking 138,000 tonnes of used fuel and 390,000 cubic metres of intermediate waste would be highly profitable, with a possible 5 per cent or $16.8 billion boost to gross state product by 2030 and an extra 9,600 jobs created directly and indirectly. It suggests a state wealth fund that spreads the benefit to future generations of South Australians could reach about $445 billion over more than 70
years.
An above-ground temporary storage facility covering an area of between 2.5 and 4 square kilometres would be needed to house metal or concrete casks containing spent fuel and intermediate waste. Permanent disposal would be in a series of tunnels that would house specially designed canisters containing used fuel and intermediate level waste. There would be multiple geological and engineering barriers to prevent outside contamination.
The enormous hurdles that would need to be overcome to turn what is technically feasible into reality are obvious. Weatherill says there would have to be bipartisan political agreement at both state and federal levels. Broad public support and specific agreement with Indigenous communities and other landholders would be necessary. Successive federal governments already have spent years trying without success to find a site for the permanent disposal of low and intermediate level waste from research reactors and medical facilities.
On the other hand, international experience suggests that it is not mission impossible. Sweden and Finland are both developing facilities for permanent long-term disposal. According to a submission to the commission, there actually was competition between two locations for the Swedish facility, with the losing bidder receiving a larger payment upfront on the basis that the winner would reap the long-term benefits. In Finland a community volunteered to host the project on the condition that the developer moved its headquarters there.
When it comes to moral arguments, there is another option: we could stop exporting uranium and with it the problems of waste disposal. The likelihood of that happening is even less than reaching agreement to take responsibility for some of the problems to which we have contributed. We may want to stop the world but we can't get off. Mike Steketee is a freelance journalist. He was formerly a columnist and national affairs editor for The Australian.

2. BURNING LIKE THE SUN
http://www.esa.int/Our_Activities/Space_Engineering_Technology/TTP2/Burning_like_the_Sun
16 March 2016

Engineers building parts of a new type of power plant for generating green energy with nuclear fusion are using their expertise from building rockets like Europe's Ariane 5 to create the super-strong structures to cope with conditions similar to those inside the Sun. A technique for building launcher and satellite components has turned out to be the best way for constructing rings to support the powerful magnetic coils inside the machine. Meaning “the way” in Latin, the International Thermonuclear Experimental Reactor, ITER, is the world’s largest nuclear fusion experiment on generating electricity and is now being built in France.

Spanish company CASA Espacio is making the rings using a method they have perfected over two decades of building elements for the Ariane 5, Vega and Soyuz rockets, as well as for satellites and the International Space Station.

“Forces inside ITER present similar challenges to space,” explains Jose Guillamon, Head of Commercial and Strategy.

“We can’t use traditional materials like metal, which expand and contract with temperature and conduct electricity. We have to make a special composite material which is durable and lightweight, non-conductive and never changes shape.”

At their centre of excellence in Spain with its track record in composites for space applications, CASA Espacio has been at the forefront of developing a technique for embedding carbon fibres in resin to create a strong, lightweight material. The composite is ideal for rocket parts because it retains its shape and offers the robust longevity needed to survive extreme launches and the harsh environment of space for over 15 years. Now, the team is using a similar technique to build the largest composite structures ever attempted for a cryogenic environment. With a diameter of 5 m and a solid cross-section of 30x30 cm, ITER’s compression rings will hold the giant magnets in place.

**Harnessing star energy**

Nuclear fusion powers the Sun and stars, with hydrogen atoms colliding to form helium while releasing energy. It has long been a dream to harness this extreme process to generate an endless supply of sustainable electricity from seawater and Earth’s crust. In a worldwide research collaboration between China, the EU, India, Japan, South Korea, Russia and the US, the first prototype of its kind is now being realised in ITER. Construction is expected to be completed by 2019 for initial trials as early as 2020. A commercial successor for generating electricity is not predicted before 2050. Designed to generate 500 MW while using only a tenth of that to
run, ITER aims to demonstrate continuous controlled fusion and, for the first time in fusion research, produce more energy than it takes to operate. Inherently safe with no atmospheric pollution or long-lived radioactive waste, one kilogram of fuel could produce the same amount of energy as 10 000 tonnes of fossil fuel. At ITER’s core is a doughnut-shaped magnetic chamber, 23 m in diameter. It will work by heating the electrically charged gases to more than 150 000 000ºC. Hotter than the Sun, the plasma would instantly evaporate any normal container. Instead, giant electromagnets will hold the plasma away from the walls by suspending it within a magnetic ‘cage’. Building something that can withstand this powerful magnetic field is an extreme engineering challenge. CASA Espacio had the answer thanks to their expertise and method for making space components. Now under construction, ITER’s rings will each withstand 7000 tonnes – the equivalent of the Eiffel Tower pressing against each one of the six rings.

Cut the cloth to fit the spacecraft
Carbon fibres are woven like fabric and embedded in a resin matrix to create a lightweight, durable and stable composite. “In the same way that you’d weave a different fabric for a raincoat than you would for a summer shirt, we can lay the fibres in different directions and alter the ingredients to adapt the resulting material to its role, making it extra strong, for example, or resistant to extreme temperatures in space,” explains Jose. For ITER, glass fibres are laid to maximise their mechanical strength and can be built up in slices and stacked like doughnuts to create the cylindrical structure. “Space expertise can provide a tremendous resource to so many companies in non-space sectors, helping them to improve their product and increase their revenues,” says Richard Seddon from Tecnalia, worked with ESA´s Technology Transfer Network, which helps companies employ technologies from space to improve their businesses. “In this case, CASA Espacio had just the right proven expertise to provide the best solution for ITER.”

3. Multi-scale simulations solve a plasma turbulence mystery
https://www.sciencedaily.com/releases/2016/03/160307152836.htm
Date:
March 7, 2016
Source:
DOE/Lawrence Berkeley National Laboratory
Summary:
Cutting-edge simulations have yielded exciting answers to long-standing questions about plasma heat loss that have previously stymied efforts to predict the performance of fusion reactors. The findings could pave the way to developing fusion as an alternative energy source.

Cutting-edge simulations run at Lawrence Berkeley National Laboratory's National Energy Research Scientific Computing Center (NERSC) over a two-year period are helping physicists better understand what influences the behavior of the plasma turbulence that is driven by the intense heating necessary to create fusion energy. This research has yielded exciting answers to long-standing questions about plasma heat loss that have previously stymied efforts to predict the performance of fusion reactors and could help pave the way for this alternative energy source.

The key to making fusion work is to maintain a sufficiently high temperature and density to enable the atoms in the reactor to overcome their mutual repulsion and bind to form helium. But one side effect of this process is turbulence, which can increase the rate of plasma heat loss, significantly limiting the resulting energy output. So researchers have been working to pinpoint both what causes the turbulence and how to control or possibly eliminate it. Because fusion reactors are extremely complex and expensive to design and build, supercomputers have been used for more than 40 years to simulate the conditions to create better reactor designs. NERSC is a Department of Energy Office of Science User Facility that
has supported fusion research since 1974. One roadblock in the quest for fusion is that, to date, computer models have often been unable to predict exactly how turbulence will behave inside the reactor. In fact, there have long been differences between predictions and experimental results in fusion experiments when studying how turbulence contributes to heat loss in the confined plasma.

Now researchers at MIT’s Plasma Science and Fusion Center, in collaboration with colleagues at the University of California at San Diego (UCSD) and General Atomics, have discovered a solution to this disparity. By performing high-resolution multi-scale simulations, the team was able to simultaneously resolve multiple turbulence instabilities that have previously been treated in separate simulations. A series of these multi-scale simulations run on NERSC’s Edison system found that interactions between turbulence at the tiniest scale (that of electrons) and turbulence at a scale 60 times larger (that of ions) can account for the mysterious mismatch between theoretical predictions and experimental observations of the heat loss.

The findings, published December 17, 2015 in *Nuclear Fusion*, could greatly improve our knowledge of what’s really going on inside the current tokamak research experiments that exist around the world and in future experimental reactors under construction or planning, the researchers noted.

"For a very long time, the predictions from leading theories have been unable to explain how much heat loss is coming from electrons in fusion plasma," said Nathan Howard, a research scientist at MIT’s Plasma and Fusion Science Center and lead author on the *Nuclear Fusion* paper. "You apply your best theories, but they have underpredicted the amount of heat loss coming from the electrons. In this particular work, we have shown that using the coupled model—where you capture both the large-scale and small-scale turbulence simultaneously—you can actually reproduce the experimental electron heat losses, in part because there appear to be strong interactions between the large-scale and small-scale turbulence that weren’t well understood previously."

**Over 100 Million CPU Hours**

Doing so requires prodigious amounts of computer time to run simulations that encompass such widely disparate scales, he emphasized. The entire study took between 100 million and 120 million CPU hours on Edison, Howard noted; each simulation required approximately 15 million hours of computation, carried out by using
17,000-30,000 processors at NERSC, making Howard the biggest user of NERSC computing time in 2014. Using an ordinary MacBook Pro to run the full set of six simulations that the team carried out, he estimates, would have taken about 3,000 years.
"I ran one entire simulation in 36-hour jobs and had to restart it about 24 times to get it to run long enough," he explained. "And that's not accounting for the amount of time it took to get jobs through the queue on the supercomputer."
For the simulations, the researchers used data from experiments conducted in 2012 at MIT's Alcator C-Mod tokamak. The multi-scale simulations used the gyrokinetic model implemented by the GYRO code developed by Jeff Candy at General Atomics. The key inputs into the simulation codes were calculated from the experimental data; the simulation results were then compared to the experimentally derived measurements.
"We are actually able to reproduce multiple aspects of the experiment with our simulations, which is important because it gives you some confidence that what you are seeing in the simulations is actually representative of reality," Howard said.

**Unexpected Findings**

For more than a decade, the general expectation by physicists had been that, because the turbulent "swirls" associated with the ions are so much larger than those associated with electrons, electron-scale swirls would simply be smeared out by the much larger turbulent ion motion. And even if the smaller swirls survived the larger ion-scale turbulence, their tiny size suggested that their effects on heat loss would be negligible.

But the new findings show that this thinking is not always correct. The two scales of turbulence can indeed coexist, the researchers found, and when they do they can interact with each other so strongly that it's impossible to predict the total heat loss accurately unless using a simulation that simultaneously resolves both scales. In fact, far from being eliminated by the larger-scale turbulence, the tiny swirls produced by electrons continue to be clearly visible in the results, stretched out into long ribbons that wind around the donut-shaped vacuum chamber that characterizes a tokamak reactor. Despite the temperature of 100 million degrees Celsius inside the plasma, these ribbon-like swirls, or eddies, persist long enough to influence how heat gets dissipated from the turbulent mass—a determining factor in how much fusion can actually take place inside the reactor.

"This is the first time a lot of these very big hypotheses have been
confirmed and shown to be operative in relevant plasma conditions," said Chris Holland, associate research scientist in the Center for Energy Research at UCSD and a co-author on the *Nuclear Fusion* paper. Looking ahead, work is already underway to modify the numerical and parallelization algorithms in GYRO so it will be able to make optimal use of many-integrated-core architectures (like Cori Phase II) as well as sophisticated accelerator hardware on emerging and future exascale platforms. "We are redesigning the GYRO code from the ground up to take advantage of these powerful but challenging new architectures and to increase the physics fidelity of the simulations," Candy said. "The challenge we are working on right now is figuring out how to get the complicated simulations, which require significant memory size and bandwidth, to work efficiently and scale well on these new platforms so we can continue to study even more complex scenarios," Holland added. "I think this is a problem that can be solved, and if we are successful it opens up exciting possibilities for new ways of doing the simulations, looking at more scales and doing more comprehensive predictions for ITER and other kinds of reactors. If we can find a way to use the new generation of platforms and make these simulations more routine, then it becomes a really exciting tool."

This research was supported by the DOE Office of Science.

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**Story Source:**
The above post is reprinted from materials provided by [DOE/Lawrence Berkeley National Laboratory](http://www.lbl.gov). *Note: Materials may be edited for content and length.*

/story_source

**Journal Reference:**

4. Engineering the future of fusion
The generation of power from nuclear fusion is not a new concept. For more than three-quarters of a century, we’ve known that stars such as the sun compress hydrogen atoms together to create helium. When these light atoms are fused together, energy is released. Nuclear fission, which is the process used by the current nuclear reactors connected to the grid, generates power by splitting heavy atoms apart to release stored energy. While fission results in nuclear waste, fusion is much cleaner. With our growing energy supply concerns, fusion power has the potential to provide abundant clean energy for centuries. However, we have yet to achieve the continuous and controlled fusion process necessary to efficiently derive power from it.

Fusion power is no longer a physics problem, but an engineering one. Controlled nuclear fusion has been achievable since 1951, when the world’s first successful fusion experiment was performed at the Los Alamos National Laboratory using a Z-pinch machine. However, transforming a laboratory
experiment into an industrial process is difficult at the best of times. This is especially true when you’re essentially extracting energy from an artificial sun. A typical fusion reactor compresses deuterium and tritium together, heating them up to 150,000,000°C in vacuum to create plasma, which is held in place by a powerful magnetic field. These magnetic fields are not unlike those seen on the warp core of the Starship Enterprise.

**Meet the JET sun**

The Joint European Torus (JET) at the Culham Centre for Fusion Energy (CCFE) is a purely experimental tokamak reactor. Built in 1977 in conjunction with EUROfusion, JET is the first stage in realising a fusion power plant. Many of the findings from JET are informing the design of ITER (Latin for “the way”), which is the next generation of experimental fusion reactor, and is currently under construction in France. ITER is expected to be three times larger than JET and weigh 23,000 tons – around the weight of 115 blue whales. However, before fusion power plants are fully realised, there are several key issues that need to be resolved. “We have performed fusion on JET: the plasma physics is largely solved,” says Damian Brennan, the active operations department head of CCFE. “Now come the engineering tasks.”

Fusion reactors are colossal machines. The reactor for JET is the size of a large house, and is contained within a building the size of an aircraft hangar. These reactors are also incredibly complex: more than 2,500 control cubicles are required to manage JET. Should
one cubicle fail, the process will not work. The findings from ITER will, in turn, lead into the creation of the first demonstration fusion power plant, called DEMO.

It takes 16 weeks of preparation to start JET, thus shutdowns are costly in both time and money. Restarts require long periods of leak testing to ensure that the vacuum pressure of $1 \times 10^{-8}$ mbar, required for plasma generation, is maintained. This is followed by a stepping up of power for the neutral beam systems and plasma, until the optimum operating conditions are achieved.

At the moment, JET can only create bursts of plasma for up to 30 seconds every 20 minutes and requires 1% of the National Grid's capacity for each burst of plasma. CCFE have to avoid running JET at times of peak electricity demands (called “pulse avoidance periods”), such as the advert breaks during popular television programmes, to avoid placing undue load on the National Grid.

Fusion power creates enormous wear on reactor components. As well as the colossal heat and pressure required for fusion, the plasma emits fast neutrons, which embed themselves in the protective tiles encasing the reactor core. Over time, these cause irradiation embrittlement, leading to accelerated degradation of the reactor’s structural materials. Thus the materials that will be exposed to the fusion process must be able to resist neutron damage, have a low activation, and be sufficiently robust that they can last for years rather than months. Materials development is therefore one of the key engineering challenges.
For a fusion power plant to become viable, it would need to be simple, compact and reliable. Furthermore, such a reactor would need to provide a “long low hum” of continuous power generation. ITER, for example, will be designed to pulse for up to an hour, with superconducting magnets enabling the extended runtime.

**Greener than coal, but safer than fission**

Despite the challenges, fusion is a highly tempting form of power generation. It doesn’t produce greenhouse gases, has a potentially abundant fuel supply, and presents a vastly reduced risk of radiation when compared with nuclear fission. The radioactive waste from a fusion reactor will be safe to recycle within a century; fission waste is an environmental burden for thousands of years. Fusion is also inherently safer than fission, as it doesn’t have the problem of stored energy. If the reactor core is ruptured, even before the crack is visible, the plasma field will collapse due to the loss of vacuum. All that will remain in the reactor is tritium, which can be safely recovered through tritium-filtration systems. However, plasma is a highly unstable state of matter: in JET, plumes of so-called edge-localised modes (akin to solar flares) can often be seen arcing from the plasma field. Such instabilities in the plasma cause disruptions that can be so strong they cause the reactor to move.

“A long time ago [JET operators] were seeing what they could do, and having a pretty good go of it, and
they had a big disruption, so they shut down early and went home,” recalls CCFE’s Brennan. “The next morning they had a phone call from one of the Oxford University seismic stations saying ‘What the hell did you lot do last night at 8.45pm? We registered an event on your site!’”

“Sun in a bottle”

Plumes of plasma dump huge amounts of energy into the reactor walls, corroding the tiles. Frozen pellets of deuterium-tritium, fired into the plasma in time with any “rattle”, can dampen the oscillations. Another method is to use resonant magnetic perturbation (RPM) coils around the plasma to dampen the disturbances.

One of the areas under the greatest stress through cyclic heating is the divertor, which removes waste heat from the plasma while the reactor is operating. This can experience a power load of up to 30MW/m². For perspective, a space shuttle’s tiles receive “only” 10MW/m² during atmospheric re-entry. Scientists are looking at using a gas buffer composed of nitrogen to absorb a proportion of the heat before it hits the divertor, thus reducing thermal loads.

Currently, the protective tiles of JET’s first wall are made from beryllium and tungsten. Previously the fusion core was protected by carbon tiles, which have a similarly low atomic mass, but these absorbed the deuterium and tritium fuels too easily, adversely affecting efficiency.

While deuterium is relatively abundant on Earth (it can be extracted from seawater), the finite supply of tritium needs to be addressed. New technology is
being developed that can breed kilogram quantities of tritium from lithium blankets wrapped around fusion reactors. “Theoretically it is possible, and mathematically quite easy, but you still need to engineer the blankets,” says Brennan.

CCFE’s Mega-Amp Spherical Tokamak Upgrade (MAST-U) is the UK’s latest fusion experiment and the next stage in fusion design. Smaller and simpler than JET, MAST-U uses a cored-apple shape. This will potentially give a far more efficient design, as it needs a lower magnetic field for the same level of performance. It will also incorporate two divertors, which can potentially distribute the thermal load. The results from MAST-U will further inform the design of ITER and allow more plasma experiments to be conducted.

Despite the numerous technical issues facing fusion power, it is expected that we will have an economically viable working fusion power plant within 50 years. “We have to,” concludes Brennan. “Because of energy resources and global warming – we have got to do something different. Now we have the sun in a bottle, let’s do the engineering!”

5. Researchers advance understanding of turbulence that drains heat from fusion reactors
February 22, 2016 by Raphael Rosen
http://phys.org/news/2016-02-advance-turbulence-fusion-
The life of a subatomic particle can be hectic. The charged nuclei and electrons that zip around the vacuum vessels of doughnut-shaped fusion machines known as tokamaks are always in motion. But while that motion helps produce the fusion reactions that could power a new class of electricity generator, the turbulence it generates can also limit those reactions.

Now, physicists at the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL) appear to have gained important new insights into what affects this turbulence, which can impact the leakage of heat from the fusion plasma within tokamaks. Understanding how fusion plasmas lose heat is crucial because the more a plasma is able to retain its heat the more efficient a fusion reactor can be. Such understanding could improve the performance of ITER, the multinational tokamak being built in France, by leading to a reduction in heat leakage.

Results of this research have been published in a series of papers, with the most recent one in *Physics of Plasmas* in December 2015. Initial observations were reported in *Physical Review Letters* in 2011 and in *Physics of Plasmas* in 2012. The research was supported by the DOE's Office of Science.

The findings build on the fact that the center of the plasma gets much hotter than the edge during the operation of a tokamak. Turbulence then tends to drive the ions and electrons in the hot central plasma towards the edge, just as the hotter water at the bottom of a tea kettle tends to mix with the cooler water at the top, keeping the water, or plasma, from getting as hot as it otherwise could. But when scientists create what's known as a "high density gradient," by making the density of the plasma change rapidly from high at the center to low at the edges, the plasma can get hotter before that heat starts to leak.

At PPPL, a team of researchers including physicists Yang Ren and Walter Guttenfelder has now shown that a steep density gradient can also reduce the strength of the electron turbulence. To continue the tea kettle analogy, a steep density gradient can weaken the intensity of the boiling. And weaker boiling, or turbulence, means that less heat escapes from the plasma.

The physicists did their research on PPPL's National Spherical Torus Experiment (NSTX), a spherical tokamak that is shaped like a cored apple, prior to its recent upgrade. "NSTX is one of the few tokamaks in the world that can obtain a direct measurement of electron-scale turbulence," said Juan Ruiz Ruiz, a graduate
student at MIT and first author of the most recent paper. Using PPPL computers, the team analyzed the data produced during 2010 NSTX experiments when scientists used a diagnostic called a high-k scattering device that beams microwaves into the plasma and measures how they scatter. The data confirmed that the turbulence was low when the density gradient was steep. To analyze how the density gradient affected the strength of the electron turbulence, the team fed information about the plasma’s temperature and density into a program run on computers at the National Energy Research Scientific Computing Center, a DOE Office of Science User Facility at Lawrence Berkeley National Laboratory in Berkeley, California. The results showed that the steep gradient reduced the strength of the electron turbulence much more than earlier theories had predicted. The paper’s discussion of electron turbulence complements MIT research that was recently reported in the journal Nuclear Fusion. Simulations of experiments on MIT’s Alcator C-Mod, a conventional tokamak that is shaped like a doughnut, found that electron-scale turbulence can contribute significantly to the much larger ion-scale turbulence that is thought to dominate heat loss in conventional tokamaks. This contribution was demonstrated in multiscale simulations, led by MIT research scientist Nathan Howard, that contradicted a common assumption that the impact of electrons was virtually negligible in conventional tokamaks. The separate Ruiz research provided further evidence of the importance of electrons to the turbulent transport of plasma. The spherical tokamak this research was based on enables the impact of electrons to be more readily seen, since the much larger ion-scale turbulence in such tokamaks is usually suppressed. "Understanding the stabilizing mechanisms of the turbulence is definitely an important task in order to gain a predictive capability in the design of future fusion reactors," said Ruiz. "Further investigation is required to understand heat losses in tokamaks, and the upgraded version of the NSTX, the NSTX-U, will certainly be used to investigate this issue in detail."


The challenge:
Lift and assemble over one million components for a first-of-its-kind experimental nuclear fusion facility in the South of France

The players:
Dodin Campenon Bernard
VFR Group

The process:
Potain tower cranes are building one of the world’s largest experimental nuclear fusion reactors at a huge site in the South of France. Built from stainless steel sections which have thicknesses ranging from 2 to 10 inches, the ITER fusion reactor will house the systems necessary for the operation of the ITER Tokamak device. The Tokamak complex is where the nuclear power will be generated. It consists of a seven-story concrete building measuring 394 feet long and 262 feet wide. There will be 17,636 tons of rebar, 5,297,200 cubic feet of concrete and 8,267 tons of steel in the structure.

The six Potain cranes working on the €300 million project include two topless tower cranes — an MDT 308 and an MDT 368 — and four traditional top-slewing tower cranes, the MD 610 M40, MD 485 B, MD 560 B and the MD 175. The cranes were supplied new to Dodin Campenon Bernard, a subsidiary of contracting giant Vinci Construction, which is managing all lifting work on site. Overall construction management is being handled by the VFR Group, a consortium made up of Vinci, Ferrovial and Razel Bec.

Laurent Moustraire, plant manager at Dodin Campenon Bernard, said the cranes are handling a succession of difficult lifts as components for the Tokamak are joined together. “For this extremely important job we needed to be certain that we were working with a professional and reliable crane provider,” he said. “Manitowoc was chosen because the team in charge of this specific project has been with us since the beginning of the tender. They fully understood the scope of what needs to be done and the constraints involved — so they were able to offer cranes specifically designed to meet our needs. Also, the presence of a Manitowoc Crane Care facility in the area was reassuring and an important factor in our final decision.”

Manitowoc’s Lift Solutions division, which provides specialist engineering support to customers, was closely involved in the crane planning and installation on the project. The structure’s unique design and complex construction process meant that a range of crane capacities were required.

Pascal Ducrot, director of Lift Solutions, said the cranes were selected not only for their capabilities but also for their proven reliability and performance on countless other jobsites. “Building an experimental
facility, which is the first of its kind, obviously means that we are undertaking something which has never been done before,” he said. “Because of this, the contractor wanted to minimize the amount of unknown factors on the project, so it was important that the cranes had proven their capabilities in real world situations. This fusion facility is highly ambitious and the climate and sensitive working conditions will test the cranes — but we are confident in their capabilities and so is the customer.”

The cranes were delivered at the end of 2014 and are expected to be on the job for at least five years. Because of the complexity of the project, the erection of the cranes took six months to complete. All were mounted on large mast sections to ensure optimum lift capability.

The Potain cranes are currently working long shifts, handling the assembly of over one million components which will be used in the Tokamak device — and which are fabricated by suppliers from all around the world. Manitowoc has ensured that Crane Care service crews visit the jobsite regularly.

“Manitowoc had a cooperative and proactive approach to managing this project,” said Jean-Claude Guitier, key accounts director at Manitowoc. “Our client appreciated the ongoing communication we provided and, combined with our technical and service support, it gave them the confidence to select Potain cranes for this contract.”

The 13-ton capacity MDT 308 has been fitted with a 115-foot jib and is working at a height of 167 feet. For the MDT 368, which has a maximum capacity of 17 tons, jib length is 180 feet and working height is 266 feet. The MD 610 M40 is the largest crane on the project, it has a 44-ton maximum capacity, its jib is configured at 213 feet in length and it has been erected to a working height of 253 feet.

The MD 485 B has a maximum capacity of 22 tons, it is working with a 197-foot jib at a working height of 246 feet. For the 27-ton capacity MD 560 B, jib length is 180 feet and working height is 210 feet.

The MD 175 B has a maximum capacity of 8 tons, jib length is 115 feet and its working height is 92 feet.

The ITER project is designed to demonstrate the large-scale production of electrical power and the self-sufficiency of tritium fuel. Made up of 39 buildings covering an area of 42 hectares, the facility is set to be the world’s biggest energy research project.

7. This $14-billion machine is set to usher in a new era of
nuclear fusion power

By Jessica Orwig
February 19, 2016 4:28 PM

The first and largest machine of its kind is currently under construction at the French scientific research center called Cadarache, which specializes in nuclear power research.

It's called ITER, Latin for "The Way," and is expected to usher in a new era of nuclear fusion-powered electricity — something scientists and engineers have been working toward for over 40 years.

By fusing two forms of hydrogen, called deuterium and tritium, together, the machine would generate 500 megawatts of power. That's ten times more energy than it would require to operate. Once completed, ITER would measure 100 feet in diameter and height, representing a new breed of nuclear fusion device. If it reaches its energy output goals, it will be the first machine of its kind to bridge the gap from fusion research in the lab to readily available fusion power for cities.

As of June 2015, construction costs for the machine exceeded $14 billion. But, in the end, experts say it will be worth it. After all, nuclear fusion is the process that powers stars like our Sun and offers a number of advantages to current energy sources if we can harness that power here on Earth:

Fusion generates non-radioactive waste that can be completely recycled within 100 years, unlike the toxic radioactive residue that today's nuclear fission reactors produce.

There's no chance of a runaway reaction because any malfunction would halt the fusion process, meaning that fusion reactors don't run the risk of a nuclear meltdown.

It's a clean source of energy compared to coal, natural gas, and crude oil.

Fusion reactors can run on seawater, offering a relatively renewable source of energy.
The problem with fusion

Right now, the biggest one is this: Fusion machines in operation today use more energy to run than they put out, which is the exact opposite of what you want from a power plant. The problem stems from the super-heated plasma that machines, called tokamaks, produce and where the fusion reactions takes place. While reaching these temperatures is a feat of engineering in and of itself, tokamaks can't sustain the plasma flow for very long. The record for the longest sustained plasma is 6 minutes and 30 seconds, which a French tokamak achieved in 2003.

This pulsing behavior, which comes with turning the plasma repeatedly on and off in short bursts, is what scientists have been trying to bypass for decades because pulsing costs too much energy to be a viable approach for net energy gain. Instead, the ideal approach is to build a machine that can produce a self-sustaining plasma. That's where ITER comes in. The plasma inside ITER will reach 150 million degrees, or ten times hotter than the center of the Sun and enough to fuse deuterium and tritium.

An important byproduct of the fusion is helium — specifically the nucleus of helium atoms. Once produced, these atoms bounce around, imparting energy in the form of heat, which helps to keep the plasma intrinsically hot, without the aid of additional, external energy input.

"That's how it will be almost completely self sustaining," Jonathan Menard, the program director of a major fusion facility at the Princeton Plasma Physics Lab (PPPL), told Business Insider. This type of fusion burning is very similar to what's happening in the core of our Sun.

The future of fusion

Another machine in Germany called Wendelstein 7-X — which was recently turned on for the first time — is also expected to generate self-sustaining plasma.
Fusion energy goal still elusive, despite progress

17 February 2016

Fusion research and development worldwide has produced notable technical advances, but still no clear path forward to efficient, economical power generation. A recent US fusion meeting highlighted both the achievements and the many challenges that remain. By Thecla Fabian

However, Menard noted that it isn't likely that this machine will generate enough surplus energy to serve as a potential nuclear fusion power plant, which is what ITER is being designed to do. Still another form of fusion reactors use lasers instead of plasma, like the National Ignition Facility in California, but that area of research still has a ways to go before it can compete with the tokamaks of the world.

"So far, the laser based systems are pretty inefficient an we think the [plasma] fusion systems are closer to having net energy," Menard said.

Construction began on ITER in 2007 and is expected to end in 2019 with the firing of its first plasma in 2020. The machine is expected to reach full deuterium-tritium fusion experiments for potential net energy gain by 2027.

In the mean time, fusion research facilities across the globe are using their tokamaks, like PPPL's National Spherical Torus Experiment, to explore different aspects of how ITER will operate.

"Particularly [we're investigating] how well those alpha particles or helium nuclei are confined," Menard said.
management deficiencies. In his presentation to the Fusion Power Associates Annual Meeting in Washington, USA, in December, he noted that the Iter Council would establish a new baseline for the project by its mid-2016 meeting. In the meantime, Iter construction and component manufacturing is proceeding at full speed.

Tony Taylor, vice president at General Atomics, called Iter an essential element for fusion energy development, burning plasma science and fusion technologies. He said tokamak confinement systems have the most advanced scientific base and have made extensive progress since they were first introduced in 1969. Iter will significantly advance the science and technology of fusion. And most important, the tokamak is the only magnetic fusion concept that is "ready".

Princeton Plasma Physics Laboratory (PPPL) is conducting systems studies of a Fusion Nuclear Science Facility (FNSF) intended to fill the gap between Iter and Demo, a demonstration fusion power plant. FNSF will be able to operate continuously for 1 to 15 days. To lay the groundwork for Demo it will be used for: fusion neutron exposure (fluence and dpa); materials development (structural, functional, coolants, breeders, shields, etc); operating temperature and other environmental variables; tritium breeding; tritium behaviour, control, inventories and accounting; long plasma durations at required performance; plasma-enabling technologies; demonstration of plant operations; subsystems; and availability, maintenance, inspectability and reliability advances.

In materials development and testing the goal will be to establish a database of components in the fast neutron environment and in the overall environment, before moving to larger operations in Demo and routine electricity production. Demo will reach power plant levels of neutron damage and will need a new class of materials that can survive in the fusion environment.

FNSF will be smaller than Demo to reduce costs and facilitate a break-in programme. The team plans a conventional aspect ratio of four; a conservative tokamak physics basis with extensions to higher performance; a 100% non-inductive plasma current; low-temperature superconducting coils made of advanced Nb3Sn; and helium cooling in the blanket, shield, divertor and vacuum vessel. Net electricity generation is not a target, but the machine could be used to demonstrate electricity generation, Charles Kessel from PPPL said. It will move from initial shakedown operations, to deuterium operations, and finally to about 23 years of deuterium-tritium operations. It will be designed to bridge what Kessel called the "tremendous" gap between Iter and Demo. The PPPL team is trying to identify what FNSF must demonstrate, identify the R&D programme to prepare for FNSF operation, and establish the connection between FNSF and Demo, as well as future fusion power plants.

Is a viable tokamak power plant possible?
Other presenters were less optimistic about the potential for Iter, or the tokamak concept, to lead to practical fusion energy. Robert L. Hirsh, who directed the US fusion energy programme in the 1970s and is now a senior energy advisor at Management Information Services Inc (MISI) in Washington, DC, said it is "time to face reality" that the Iter tokamak will never be commercially viable. It can, however, provide valuable knowledge and experience.

One big issue with the economics of tokamak fusion power is the time required for superconducting toroidal field coils to warm up and cool down, Hirsh said. China’s Experimental Advanced Superconducting Tokamak (EAST) took about 18 days to cool from room temperature to 4.5K after a December 2006 quench. The Iter cool-down is estimated at roughly 30 days. A 30-day heat up/cool-down outage in a commercial power system "would have a major, negative impact on plant economics", Hirsh said.

**Possible regulatory concerns**

Regarding waste, runaway reactions are not possible in fusion devices. And the radioactive waste from a tokamak consists of activated metals, which would be shorter-lived and less hazardous than used fission fuel. However, Hirsh said radioactive waste handling, storage and disposal would still be a major regulatory concern.

Assuming that the blanket of an Iter-class tokamak must be replaced every three years due to radiation damage, the radioactive waste produced in a continuously operating Iter tokamak would be 675t/year. This is more than a fission reactor, which produces approximately 150t/year of spent fuel. While its radioactivity and toxicity is much greater and longer-lived than Iter fusion waste, nuclear regulators require waste from a fusion reactor to be handled in a similar manner, or at least under very stringent standards, Hirsh said.

Aside from waste, Hirsh identified three major regulatory concerns: superconducting magnet quench, plasma disruptions and tritium containment.

Regulators are particularly concerned about superconducting magnet quenching, which is a low-probability event with an explosive energy release. A superconducting magnet quench on Iter, for example, could release more than 40GJ, or the equivalent of 10t of TNT. Hirsh pointed out that this is the same explosive power as a World War II era Blockbuster Bomb. The threat of an explosive superconducting magnet quench will require an Iter-class tokamak to be adequately contained. Given the size of the tokamak, a blast-proof containment structure would be extremely expensive, he said.

Plasma disruptions are another area of regulatory concern. Tokamaks operate within limited parameters. Outside this, sudden losses of energy confinement, known as disruptions, can occur. These disruptions cause major thermal and mechanical stresses to the
structure and walls. Hirsh quoted physicist Sarah Angelini from Columbia University, who said: "In a large-scale experiment such as Iter, disruptions could cause catastrophic destruction to the vacuum vessel and plasma facing components." Regulators will focus on disruptions, identify all possible triggers and potential cascades, and require fail-safe protection, Hirsh said.

Tritium diffuses through solid materials, especially at high temperature. Vacuum and energy injection ports on tokamaks will allow tritium leakage into the reactor hall, as will equipment breakdowns and damage to the vacuum vessel. NRC's tritium dose limits for radiation workers and the general public are significantly lower than the levels of radiation exposure known to cause health effects in humans. Regulators will require expensive fail-safe protections.

The public has been told that fusion power will be economic, safe and environmentally attractive, Hirsh said, and warned that this could backfire. Utilities also will be acutely aware of any NRC restrictions and concerns, Hirsh said, and their interest could quickly evaporate.

Tokamaks also face major operability questions when considered as power generators rather than research devices. Hirsh pointed to divertor durability during commercial operations as a major issue. Recent research indicates that no solid material, including tungsten, can operate under expected Iter conditions for a reasonable period of steady-state operation. Hirsh said that a 2015 US DOE fusion workshop concluded that the knowledge base of tokamak divertor physics cannot specify a divertor solution, "in fact, we do not know that a solution exists, even in principle". Without that, Iter-class tokamaks will not operate for very long, Hirsh said.

**Stellarator demo**

Presenters from Europe and Japan said that they were looking at alternate concepts for Iter's follow-up Demo. Chief among the concepts under consideration are stellarators, spherical tokamaks (a hybrid that combines features of both the tokamak and the stellarator) and inertial confinement options.

The 10 December 'first plasma' at Germany's Wendelstein 7-X, the world's largest stellarator, a week before the FPA meeting, provided a fitting backdrop to several presentations on stellarators' potential to serve as the basis for a future Demo device. W7-X, a superconducting stellarator, is numerically optimised for transport and magnetohydrodynamic (MHD) stability. Its maximum expected heating pulse is 30 minutes, said Mike Zarnstorff from PPPL.

A number of stellarator characteristics may be needed to make fusion commercially viable, Zarnstorff said. These include: no disruptions; no current drive and low recirculating power with higher fusion gain; steady-state magnetic fields and plasma; and sustained high pressure (with beta 5% or above). However, the stellarator configuration must be
optimised to achieve these characteristics and this is the focus of aggressive stellarator research programmes in the EU and Japan. Those countries have mapped out a path to Demo that includes the stellarator option, and both have large superconducting stellarator experiments: Europe has W7-X (above) and Japan has the LHD, which has operated since 1998.

Japan’s Demo strategy is to develop the tokamak and the stellarator/heliotron in parallel. In 2027, Japan will assess progress of both and it will decide on a Demo approach and construction schedule around 2030.

Japan plans to begin deuterium experiments in LHD in February 2017, and is currently upgrading it to include neutral beam injection, electron cyclotron heating, ion cyclotron range of frequency heating and advanced diagnostics. The goals of the deuterium experiments are to maximise confinement performance, study isotope effects on plasma confinement, demonstrate confinement of high-energy ions and validate modelling for extrapolation. Additional research will cover MHD stability at high-beta and low collisionality, divertor optimisation and plasma wall interactions.

Like Japan, the EU hopes to make a decision on Demo by 2030. Over the next 14 years, the EU intends to develop the basis for a W7-X-like fusion power plant; develop and demonstrate power-production scenarios for a stellarator Demo; validate models and the design approach; develop and demonstrate a steady-state divertor; and produce 10MW of power for 30 minutes.

The US role in stellarator research is more oriented to basic research, improving the numerical modelling and validation of 3D physics understanding, improved 3D optimisation, and designs for stellarator pilot plants and scoping studies for PPPL’s Fusion Nuclear Science Facility.

PPPL in the USA is interested in research on both the spherical tokamak and the stellarator that could lead to a Demo-scale power plant, said PPPL’s Stewart Prager. The lab also is pursuing liquid metal research as a novel solution to the first wall problem. He noted a large gap in the world stellarator programme: there are only two large stellarators and only one is optimised. This leaves an opening for PPPL to take a position that includes forefront stellarator research.

Stellarators, he said, are "arguably the most physics-optimised fusion concept".

PPPL has also recently completed a major upgrade of its National Spherical Tokamak Experiment (NSTX-U), which will help with establishing sustained, high-performance plasmas, advancing both toroidal confinement physics for Iter and beyond, and the spherical tokamak as a candidate for a next-step fusion facility.

A key question is whether deuterium-tritium (DT) stellarator operation needed before developing plans for Demo?
It is clear that DT operation would reduce risk, but add a step to the process. Participants at a March 2015 meeting in Japan debated whether validating integrated models using Iter and non-DT large experiments could reduce these risks. The general conclusion was that DT operations would be needed, but that a final decision would depend on research advances. The EU Demo plan calls for DT stellarator operation before a decision is made on the design concept.

**Fusion materials**

The environmental attractiveness and economic competitiveness of all fusion power will directly depend on the materials used in power plants, said Steve Zinkle from Oak Ridge National Laboratory. Environmental attractiveness will require materials that can protect the public and the environment from radioactive releases and accidents. The waste should be low-hazard and short-lived, with reduced activation materials and low-tritium sequestration materials. Economic competitiveness will depend on high-performance and long-lived materials, short repair and outage times and high-thermodynamic efficiency.

The major fusion materials development challenges include:

- **Plasma-facing components: Will tungsten work, and how long can it survive without embrittlement?**
- **Tritium containment: Can materials be developed that will prevent tritium leakage and allow for on-line extraction and fuel reprocessing?**
- **Non-structural materials, including plasma diagnostics (e.g. optical fibers, electrical insulators), plasma heating feedthrough insulators and next generation magnet systems and ceramic breeders. Many of the materials now used have no operating experience in a DT environment as expected in Demo. Structural systems options would work well for the first year, but new, longer-lived options are needed for commercial systems.**

In structural materials, the fusion community can leverage work being done for fission power plants, and research and development NNSA is doing for inertial confinement fusion and the weapons programme. However, in other areas, there is not such a strong synergy, particularly in tritium containment and non-structural materials.

Tritium containment presents a particular problem. Strong neutron bombardment creates microscopic cavities that retain significantly higher amounts of tritium than unirradiated materials. Kessel pointed out PPPL's Tokamak Fusion Test Reactor had a "massive" number of cavities that trapped more than 100 times as much tritium as expected. This level of tritium retention could be a public safety hazard in a machine as large as Demo, or even Iter. Researchers also are working on low-activation steels. Kessel said it is now possible to computer design high-performance steels.
Computational thermodynamics modeling has identified potential new thermomechanical treatment processes for commercial 9-12% chromium steels but some, such as hot rolling, may be hard to implement on some product forms and cannot be used in weldments. EU researchers have embarked on a programme to design next-generation reduced-activation ferritic-martensitic steels. This includes developing a computational model for the selection of 9%Cr steels optimised for high-temperature applications. Mechanical properties and microstructural investigations are under way, with irradiation tests planned for 2016-2017.

Fusion researchers are looking at a broader range of possible materials, including advanced ceramics and materials developed for other applications. Kessel pointed to SiC/SiC composites now being qualified for jet turbines by a joint venture of GE and Snecma. The first deployments will be the Airbus 320neo in 2016 and the Boeing 737 MAX in 2017. Developers estimate that higher temperatures and lower weight will produce fuel savings of about 15%.

Two new SiC fibre and CMC fabrication plants for the new composite will be built in the USA. Successful use of the composites in the airline industry should spur development of improved SiC fibres and lower cost composites for other applications, including possibly fusion, Kessel said. Currently, the composites cost between 100 to 1000 times more than metals for the same applications.

Kessel pronounced himself “bullish” on structural materials, noting the high performance structural materials available for nuclear environments. There is a high level of confidence in the suitability of such materials for fission neutron environments, but uncertain suitability for fusion beyond about 5MW-yr/m2.

Japan maps Demo requirements

In a report published in September, a high-level team of Japanese fusion scientists defined the goal of Demo as demonstrating fusion energy to be economically and socially competitive with other power plants. It should be aimed at steady and stable electricity generation at levels beyond several hundred megawatts, amenable to commercialisation and able to breed enough tritium for a self-sufficient fuel cycle.

Hiroshi Yamada, science advisor to Japan’s Ministry of Education, Culture, Sports, Science and Technology, led the team that established the technology bases required for Demo. The team’s report, Development of Strategic Establishment of Technology Bases for a Fusion Demo Reactor in Japan, was published online on 26 September 2015 and is available in English.

Yamada said that the ministry has called for development of alternative concepts such as helical and laser systems, along with tokamaks, “in a strategically linked manner”.

29
The UK government has launched the initial phase of its small modular reactor (SMR) competition with a call for initial expressions of interest. It has also announced that an SMR Delivery Roadmap will be published later this year.

Last November, the government announced plans to invest at least £250 million ($352 million) over the next five years in an "ambitious" nuclear research and development program to include a competition to identify the best value SMR design for the UK. In his 2016 Budget speech on 16 March, British Chancellor George Osborne announced, "We're now inviting bids to help develop the next generation of small modular reactors".

Yesterday, the Department of Energy and Climate Change (DECC) officially launched the first phase of the competition by publishing a request for expressions of interest.

DECC said the objective of the initial phase is "to gauge market interest among technology developers, utilities, potential investors and funders in developing, commercializing and financing SMRs in the UK." It said this stage would be a "structured dialogue" between the government and participants.

The USA's NuScale Power was quick to confirm that it will put its SMR forward as
part of the UK's competition. It also confirmed that talks with potential developers interested in deploying the technology in the UK in the late 2020s are advancing, as are plans to "put British nuclear engineering and advanced manufacturing at the forefront of that deployment."

**Researched and written by World Nuclear News**

### 10. Reactor vessel in place at Tianwan 4
18 March 2016


The reactor pressure vessel for the fourth unit of the Tianwan nuclear power plant in China's Jiangsu province has been installed. The Russian-supplied VVER-1000 is scheduled to start up next year.

The pressure vessel was produced in Russia by OMZ subsidiary Izhorskiye Zavody under a contract awarded in 2010 for the manufacture of the vessels for both Tianwan units 3 and 4. The vessel was transported from St Petersburg on an ocean-going transport ship which delivered it to the port of Lianyungang in Jiangsu province. It was then unloaded and put onto a barge for the remainder of the journey to the Tianwan site. The component - weighing 323 tonnes and measuring over 11 meters in length and 4.5 meters in diameter - arrived at the Tianwan site on 24 February.

China National Nuclear Corporation (CNNC) said in a statement today that pressure vessel hoisting work began on 10 March. Once manoeuvred horizontally through the hatch in the unit's containment building, the final operation was carried out yesterday to flip the vessel vertically and locate it on its support ring. CNNC said this took about three hours and 40 minutes, noting this was about one hour less for the comparable task for Tianwan 3 that was completed in May 2015.

Tianwan 4 is the second of two AES-91 VVER-1000 units designed by Gidropress, a subsidiary of Russian state nuclear corporation Rosatom. Two similar units have been in commercial operation at the Tianwan site since 2007. AtomStroyExport, another Rosatom subsidiary, is the main contractor, supplying the nuclear island. Construction work began on unit 3 in December 2012, with unit 4 following in September 2013. The units are expected to start operation in 2016 and 2017, respectively.

The Tianwan plant is owned and operated by Jiangsu Nuclear Power Corporation, a joint venture between CNNC (50%), China Power Investment Corporation (30%) and Jiangsu Guoxin Group (20%).

**Researched and written by World Nuclear News**
EDF Energy chiefs invited to UK Parliamentary hearing
17 March 2016

The UK's Energy and Climate Change Committee has called EDF Energy, and other energy companies planning to build reactors in the UK, to Parliament on 23 March to give evidence on the future of the nuclear industry.

Chair of the Committee, Angus MacNeil, said today that the government is "counting on" new nuclear to supply a significant proportion of the UK's demand for low-carbon baseload power in future. "The focus right now is on Hinkley Point C but there are other important projects in the pipeline. Serious questions are being raised about the cost and viability of the Hinkley project and the value for money for taxpayers," MacNeil said.

The Committee will hear from commentators that have "raised concerns" about financing nuclear projects, he said, adding, "We will also question the Chief Executive of EDF and other companies planning to build reactors about the challenges for new nuclear across the UK."

Participants, or 'witnesses', at the meeting will include Vincent de Rivaz, EDF Energy CEO and Humphrey Cadoux-Hudson, EDF Energy managing director for nuclear new build. Zhu Minhong, general manager of international nuclear business development, and general director of UK nuclear projects, at China General Nuclear, will also give evidence. Other witnesses will be: Tom Samson, CEO of NuGeneration; Alan Raymant, chief operating officer of Horizon Nuclear Power; Peter Atherton, managing director and head of European utility sector research at Jefferies; Simon Taylor of the Judge Business School at the University of Cambridge; and Douglas Parr, chief scientist and policy director at Greenpeace UK.

The planned Hinkley Point C plant - the first new nuclear power station built in the UK in almost 20 years - is scheduled to begin operating in 2025. Under a deal agreed last October, China General Nuclear will take a 33.5% stake in EDF Energy's £18 billion ($28 billion) project to construct the plant. In addition, the two companies will develop projects to build new plants at Sizewell in Suffolk and Bradwell in Essex, the latter using Chinese reactor technology.

In January, EDF Energy's French state-owned parent company, EDF, again delayed making a final investment decision for the construction of the Hinkley plant. A decision had been expected by the end of 2015. Earlier this month, the chief executive of EDF, Jean-Bernard Levy, said he wants to reach a final decision soon on
inventing in the plant after the resignation of the company’s finance chief, Thomas Piquemal.

NuGeneration - a 60%/40% joint venture between Toshiba and GDF Suez - in 2014 confirmed plans to build three Westinghouse AP1000 pressurized water reactors at Moorside in West Cumbria by the end of 2026 with a total capacity of 3.4 GWe. The first unit is expected to begin operating by the end of 2024. A final investment decision is expected to be taken by the end of 2018.

In January, the UK’s Office for Nuclear Regulation (ONR) announced there has been some program "slippage" in a number of topic areas for the generic design acceptance (GDA) of the Westinghouse AP1000 nuclear reactor design. In its latest quarterly report on GDAs, the ONR said that Westinghouse is working to “re-baseline the overall program” with the objective of enabling the ONR and the Environment Agency to make decisions about issuing a Design Acceptance Confirmation and Statement of Design Acceptance Confirmation in January 2017, as per the current schedule. Horizon Nuclear Power, the wholly owned UK subsidiary of Japan’s Hitachi, plans to deploy the UK Advanced Boiling Water Reactor at two sites - Wylfa Newydd, which is on the Isle of Anglesey, and Oldbury-on-Severn, in South Gloucestershire. In January, Hitachi announced the incorporation of a new UK company - Hitachi Nuclear Energy Europe - as part of its strategy to enhance its UK presence for the engineering, procurement and construction of Horizon's new nuclear power plant development at Wylfa Newydd. Hitachi Nuclear Energy Europe will lead Tokyo-headquartered Hitachi’s work in a proposed joint venture with potential partners Bechtel Management Company and JGC Corporation.

Research and written by World Nuclear News

12. **Hualong One joint venture officially launched**

17 March 2016


**Hualong International Nuclear Power Technology - the joint venture between China General Nuclear (CGN) and China National Nuclear Corporation (CNNC) to promote the Hualong One reactor design in export markets - was officially inaugurated today.**

In 2012 central planners in Beijing directed CNNC and CGN to 'rationalise' their reactor programs. This meant CNNC's ACP1000 and CGN's ACPR1000 were 'merged' into one standardised design - the Hualong One.

In fact, each company has its own supply chain and their versions of Hualong One will differ slightly (units built by CGN will use some
features from the ACPR1000), but the design is considered to be standardised. It is set for wide deployment in China as well as export to other countries.

In late December last year, CGN and CNNC announced that they had agreed to create a 50-50 joint venture to promote China's "third-generation" nuclear reactor design, Hualong One, in overseas markets. At that time, the two companies signed the shareholder contribution agreement and the articles of association for creating Hualong International. The agreement to form the Hualong company followed the two companies' signing of a "technology integration agreement" in August 2015.

In separate statements today, the two companies said the joint venture had now officially begun operating. They said that since December, Hualong International had completed industrial and commercial registration in Beijing. Also, CGN's Zou Yongping has been appointed chairman of the new company, while CNNC's Xu Pengfei will be its general manager. Meanwhile, CGN and CNNC have been working on integrating their technologies into the export model of the Hualong One.

Hualong International will "actively implement" China's nuclear power development strategy, which is "committed to the continued integration and development of Hualong One as an independent third-generation nuclear power technology, with the unified management of the Hualong brand, intellectual property and other related assets at home and abroad", CGN and CNNC said. The company will promote Hualong One as the Chinese nuclear power industry's "flagship brand".

Construction of two Hualong One units is already under way at CNNC's Fuqing plant in Fujian province, as well as the first of two such units at CGN's Fangchenggang plant in Guangxi province. Although it is still officially listed as being ACP1000, Pakistan's Karachi Coastal Power station is likely to be the first export of Hualong One units.

Under the Strategic Investment Agreement signed last October, CGN agreed to take a 33.5% stake in the Hinkley Point C project in Somerset, England as well as jointly develop new nuclear power plants at Sizewell in Suffolk and Bradwell in Essex. The Hinkley Point C and Sizewell C plants will be based on France's EPR reactor technology, while the new plant at Bradwell will feature the Hualong One design. As part of that agreement, CGN agreed to form a joint venture company with EDF Energy to seek regulatory approval for a UK version of the Hualong One design.

The following month, China and Argentina signed an agreement to build a Hualong One reactor as the South American country's fifth nuclear power unit.

Researched and written by World Nuclear News
13. **Reactor vessel delivered for China's first HTR**

15 March 2016

The first of two reactor pressure vessels for the demonstration HTR-PM high-temperature gas-cooled reactor unit under construction at Shidaowan in China's Shandong province has been delivered to the construction site.

The component - about 25 meters in height and weighing about 700 tonnes - was manufactured by Shanghai Electric Nuclear Power Equipment. It successfully completed factory acceptance on 29 February and was dispatched from the manufacturing plant on 2 March. The pressure vessel arrived at the Shidaowan site on 10 March, plant owner China Huaneng Group announced the following day.

The company said it sent the project leader and supervision staff to supervise the entire manufacturing process of the reactor vessel, which it claims is the world's largest and heaviest.

Work began on the demonstration HTR-PM unit - which features two small reactors and a turbine - at China Huaneng's Shidaowan site in December 2012. China Huaneng is the lead organization in the consortium to build the demonstration units together with China Nuclear Engineering Corporation (CNEC) and Tsinghua University's Institute of Nuclear and New Energy Technology, which is the research and development leader. Chinergy, a joint venture of Tsinghua and CNEC, is the main contractor for the nuclear island.

The demonstration plant's twin HTR-PM reactors will drive a single 210 MWe turbine. It is expected to start commercial operation in late 2017. An earlier proposal was for 18 further 210 MWe units - giving a total capacity of 3800 MWe - at the Shidaowan site, near Rongcheng in Weihai city, but this has been dropped.

A proposal to construct two 600 MWe HTR plants - each featuring three twin reactor and turbine units - at Ruijin city in China's Jiangxi province passed a preliminary feasibility review in early 2015. The design of the Ruijin HTRs is based on the smaller Shidaowan demonstration HTR-PM. Construction of the Ruijin reactors is expected to start next year, with grid connection in 2021.

*Researched and written by World Nuclear News*
The Nuclear Fuel Cycle Royal Commission has reached an important milestone with the release of its Tentative Findings into the opportunities and risks represented by increasing the State’s participation in nuclear fuel cycle activities.

Commissioner Kevin Scarce released the Tentative Findings document in Adelaide today ahead of a five-week feedback period.

“The Tentative Findings reflect the Commission’s current thinking and the evidence behind this,” Commissioner Scarce said.

“We have taken the somewhat unusual step of releasing our Tentative Findings to share with the community the evidence gathered into nuclear fuel cycle activities because we want South Australians to be involved in further refining, informing and improving the Commission’s report, which will be delivered in May.”

The key observations that frame the Commission’s Tentative Findings include that:

• South Australia can safely increase its participation in nuclear activities and, by doing so, significantly improve the economic welfare of the South Australian community;

• Community consent would be essential to the successful
development of any nuclear fuel cycle activities;

- The management of the social, environmental, safety and financial risks of participation in these activities is not beyond South Australians, and;

- Long-term political decision-making, with bipartisan support at both state and federal levels, would be a prerequisite to achieving progress. The 42-page document includes 155 individual findings, with the key Tentative Findings including:

  - **EXPLORATION, EXTRACTION AND MILLING**

    **Key Finding:** An expansion of uranium mining has the potential to be economically beneficial. However, it is not the most significant opportunity.

  - **FURTHER PROCESSING AND MANUFACTURE**

    **Key Finding:** In an already oversupplied and uncertain market, there would be no opportunity for the commercial development of further uranium processing capabilities in South Australia in the next decade. However, fuel leasing, which links uranium processing with its eventual return for disposal, is more likely to be commercially attractive, creating additional employment and technology-transfer opportunities.

  - **ELECTRICITY GENERATION**

    **Key Finding:** Taking account of future demand and anticipated costs of nuclear power under the existing electricity market structure, it would not be commercially viable to generate electricity from a nuclear power plant in South Australia in the foreseeable future. However, Australia’s electricity system will require low-carbon generation sources to meet future global emissions reduction targets. Nuclear power may be necessary, along with other low carbon generation technologies. It would be wise to plan now to ensure that nuclear power would be available should it be required.
**MANAGEMENT, STORAGE AND DISPOSAL OF WASTE**

*Key Finding:* The storage and disposal of used nuclear fuel in South Australia would meet a global need and is likely to deliver substantial economic benefits to the community. An integrated storage and disposal facility would be commercially viable and the storage component could be operational in the late 2020s. Such a facility would be viable and highly profitable under a range of cost and revenue assumptions. By way of example, financial assessments and economic modelling provided to the Commission by external expert consultants indicate that a storage and disposal facility could:

- Generate total revenue of more than $257 billion, with total costs of $145 billion over 120 years;
- Expressed in annual terms, generate State revenue of more than $5 billion per year over the facility’s first 30 years of operation and $2 billion per year over the following 40+ years at which point waste receipts nominally conclude; and
- Generate approximately 1500 full time jobs – peaking at between 4000-5000 – during the 25-year construction process and 600 full time jobs once operational.

The scenario is based on a storage capacity of 138,000 tonnes (~13%) of the projected global used fuel inventory and is based on a very conservative waste assumption that assumes no new (currently unplanned light water) reactors become operational after 2030. The Commission’s view is the facility would need to be further supported with construction of a dedicated port facility, airport and rail freight line. This infrastructure spend has been included in the scenario cost base.

To deliver long-term benefits to future generations of South Australians, a special arrangement such as a State Wealth Fund should be established to accumulate and equitably share the profits from the storage and disposal of waste. Using that proposition, if a portion of gross revenue (15%)
and all profits from the operations were invested in a State Wealth Fund and 50% of resulting interest retained, this could generate more than $6 billion a year for over 70 years. Approximately $445 billion would accumulate before notional waste deliveries are planned to cease. Provision has also been made within the cost base for a $32 billion Reserve Fund to cover whole-of-life maintenance, both for long-term monitoring and post-closure of the facility.

The Commission has begun a five-week feedback period, commencing with a week of public presentations to be held across the state. The closing date for responses is 5pm, Friday 18, March, 2016.

“The next five weeks gives the community the opportunity to consider the evidence upon which the Tentative Findings are based and what they mean, and to provide feedback on where they believe we may have erred in a matter of fact or in the omission of evidence,” he said.

“We will then review that feedback as we refine our final report ahead of its release.”

The Commission’s final report will be delivered on 6 May, 2016. The Tentative Findings, the full list of public meetings and information regarding the feedback mechanisms are available for download at www.nuclearrc.sa.gov.au.

15. Experimental Highlights

Targeting Extreme Physics

As the pursuit of fusion ignition continues on NIF, LLNL researchers also are conducting increasingly challenging experiments that peer more and more deeply into the behavior of materials under extreme temperatures and pressures. And a key to the success of these experiments is the development and refinement of intricate, precisely fabricated targets that meet the researchers’ needs.

NIF’s millimeter-sized targets are used in inertial confinement fusion (ICF), high energy density (HED), and Discovery Science experiments that often are
possible only under the extreme conditions that exist in the NIF Target Chamber. While some target designs can be used more than once, others must continually be revamped in response to experimental results and the requirements of NIF’s increasingly sophisticated diagnostics.

“All of these targets are designed to re-create the physics regimes our investigators require to probe matter in extreme environments,” said NIF & Photon Science Principal Associate Director Jeff Wisoff in a commentary in the January/February 2016 issue of Science & Technology Review. “Indeed, NIF’s suite of capabilities, including diagnostics, laser attributes, staff expertise, as well as targets, have evolved in response to the extreme physics necessary for our investigators’ research.”

Targets designed for ICF experiments, for example, include a variety of hohlraum shapes, sizes, and linings as well as target capsule materials ranging from plastic to beryllium and high-density carbon, or diamond. The targets provide information on such things as shock timing, capsule implosion shape, implosion velocity, and the extent to which the colder deuterium-tritium fuel in the capsule mixes with the “hot spot” in the core. Researchers also are investigating several different methods of suspending the target capsule in the center of the hohlraum, in an effort to reduce implosion instabilities caused by the ultrathin polymer “tents” currently used.

HED material strength experiments measure the strength of a variety of materials at pressures never previously achieved in a laboratory. By “ramping,” or gradually increasing the pressure on the sample, the experiments can avoid forming a shock wave that increases the sample’s temperature and thus limits the types of data that can be obtained.

Among NIF’s most exotic targets are the TriStar and QuadStar targets—three or four hohlraums joined together for Discovery Science experiments designed to study the star-formation process in molecular hydrogen clouds, such as the famous “Pillars of Creation” in the Eagle Nebula (see “Unlocking the Secrets of Star Creation”).

In the most recent Eagle experiment, the NIF lasers drove four hohlraums one after another, from times of 0 to 15 nanoseconds, 15 to 30 ns, 30 to HED material strength experiments measure the strength of a variety of materials at pressures never previously achieved in a laboratory. By “ramping,” or gradually increasing the pressure on the sample, the experiments can avoid forming a shock wave that increases the sample’s temperature and thus limits the types of data that can be obtained. Among NIF’s most exotic targets are the TriStar and QuadStar targets—three or four hohlraums joined together for Discovery Science experiments designed to study the star-formation process in molecular hydrogen clouds, such as the famous “Pillars of Creation” in the Eagle Nebula (see “Unlocking the Secrets of Star Creation”).
In the most recent Eagle experiment, the NIF lasers drove four hohlraums one after another, from times of 0 to 15 nanoseconds, 15 to 30 ns, 30 to 45 ns, and 45 to 60 ns,

*The QuadStar target used in a September 2015 Eagle experiment.* for a total x-ray drive length of 60 ns. The multi-hohlraum array simulates a bright, sustained stellar source, and the NIF Eagle science package mocks up a radiatively-driven, star-forming cloud of molecular hydrogen that mimics the cluster of massive stars illuminating the Eagle Nebula.

These are just a few of the roughly 430 targets manufactured for NIF from September 2014 to October 2015—at least 190 of which had unique fabrication requirements. “Each target has been carefully designed by teams of scientists and engineers, manufactured to extraordinary tolerances by talented technicians, assembled in clean rooms rivaling those in semiconductor plants, and inspected with microscopes and other fine-scale tools,” Wisoff said. “We depend on a team of highly skilled engineers, scientists, machinists, and technicians to develop the means to fabricate and assemble them into exquisite, minuscule objects.”

To help meet an ambitious production goal of nearly 500 targets for Fiscal Year 2016—needed to keep up with NIF’s ever-increasing shot rate (see “Target Fabrication Steps Up to the Challenges”)—engineers have established faster fabrication and assembly methods, including modular and batch processing to speed deliveries and reduce nonuniformities, and installed several new target-assembly robots in the Target Fabrication Facility.

Components for NIF targets are produced by LLNL, General Atomics of San Diego, and Schafer Corporation of Livermore. Experts from the three institutions make up the assembly and inspection teams, and construction of the final targets is conducted at LLNL.

For more information on the types, requirements, and fabrication challenges of NIF targets, see “A Growing Family of Targets for the National Ignition Facility,” *Science & Technology Review*, January/February 2016.

For a comprehensive review of the kinds of fundamental science experiments that have been enabled by NIF and other high-power lasers, pulsed-power facilities, and next-generation light sources, see “From microjoules to megajoules and kilobars to gigabars: Probing matter at extreme states of deformation,” *Physics of Plasmas*, Sept. 17, 2015.

16. Papers and Presentations

**Controlling Early Hot Electrons in NIF Implosions**
Controlling Early Hot Electrons in NIF Implosions

One of the factors that can limit the performance of NIF inertial confinement fusion (ICF) implosions is the presence of suprathermal, or “hot,” electrons generated by laser-plasma instabilities (LPI) in the NIF hohlraum during the early stages of the laser pulse. Hot electrons can penetrate the shell of the target capsule inside the hohlraum and preheat the fusion fuel, reducing its compression and ability to achieve ignition. The challenge would be compounded if the hot electrons were “beamed,” or focused on specific areas of the capsule, but until now there was no way to know if the beaming theory was correct.

To date, therefore, laser pulses have been carefully designed to avoid these issues, drawing on the results of extensive experimental data obtained in collaboration with colleagues from the Laboratory for Laser Energetics (LLE) at the University of Rochester on the OMEGA laser prior to the National Ignition Campaign on NIF.

Although hot-electron production has been routinely monitored on a shot-to-shot basis on NIF by measuring the characteristic x-rays emitted by these electrons, these measurements could not tell if the electrons were beaming at the capsule. If they were, researchers could have been drastically underestimating their impact on the implosion.

In a Physical Review Letters paper published on Feb. 17, LLNL researchers reported on experiments and simulations revealing for the first time the directionality of the hot electrons and the extent of capsule preheat they can cause. By imaging the hard x-rays caused by the impact of the suprathermal electrons, they were able to quantify the location and energy of electrons deposited in the capsule.

Hot electrons are generated in the first stage, or “picket,” of the laser pulse as the laser beams blow through the hohlraum’s laser entrance hole (LEH) plastic windows that retain the hohlraum gas fill. The new experimental data, combined with Monte Carlo calculations, indicate that for most experiments the hot electrons are emitted nearly isotropically (equal amounts in all directions) from the LEH.

But the new technique revealed that under certain circumstances, a significant fraction of the suprathermal electrons can be emitted in a collimated beam directly toward the capsule poles. In these cases, their local energy deposition can reach more than 100 times more than when electrons are emitted isotropically. Averaged over the entire capsule, this would lead to a factor of 20 more heating in a fuel capsule than would have been interpreted assuming isotropic electrons.

The researchers also were able to quantify the spatial uniformity of energy deposition over the capsule using the new technique. “Our results...show
that the electron energy deposition in the DT (deuterium-tritium) fuel is spatially nonuniform at the capsule, giving more preheat at its poles than at the equator, by a factor of about 2 in cases of isotropic emissions and up to a factor of about 30 in cases of beaming,” they said.

The technique employed to date to control the amount of early-time hot electrons consisted of adjusting the power and duration of the low-intensity prepulse, or “toe,” of the laser pulse as well as the level of the ensuing higher-intensity picket. The study confirmed that this technique has kept hot electrons below levels of concern in most ICF implosions. In the future this technique will help ensure that new ICF designs are steered away from too much early-time hot-electron preheat.

Lead author Eduard Dewald was joined on the paper by LLNL colleagues Fred Hartemann, Pierre Michel, Jose Milovich, Arthur Pak, Nino Landen, Laurent Divol, Harry Robey, Omar Hurricane, Tilo Döppner, Félicie Albert, Benjamin Bachmann, Nathan Meezan, Andy MacKinnon, Debbie Callahan, and John Edwards, and by Matthias Hohenberger of LLE.

17. The Risks in Hoverboards and Other Lithium-Ion Gadgets

Disruptions

By NICK BILTON MARCH 2, 2016
http://www.nytimes.com/2016/03/03/fashion/the-risks-in-hoverboards-and-other-lithium-ion-gadgets.html?_r=0

There could be a bomb in your house, and you put it there.

In recent years, we have brought home a slew of new battery-powered devices, including smartphones, laptops, tablets, electronic cigarettes, electric cars, drones, hand-held vacuums and toys.

But while we celebrate how these devices have improved our lives, we haven’t realized that many are also capable of exploding because of battery malfunctions.

At first, it was just the odd gadget erupting into flames,
an anomaly of a single battery that may have been defective. But as of late, such malfunctions seem to be happening every week or so.

Just scan the headlines from the last month. There was the man in Owensboro, Ky., who was at a gas station convenience store when an e-cigarette battery exploded in his pocket, causing severe burns along his right thigh.

There was a hoverboard, the toy of the moment, that exploded in a home in Highland Park, Ill., engulfing the house in flames and causing extensive damage. (Luckily, no one was home.)

And last week, a teenager in Castle Rock, Colo., ended up in hospital after his vaporizer battery exploded in his pocket while he was at school.

There have been hundreds of similar reports in recent months, with homes catching fire and e-cigarettes exploding in people’s pockets (and sometimes in their faces while smoking).

But these instances can happen while airborne, too. The Federal Aviation Administration has documented hundreds of cases involving batteries from e-cigarettes, laptops, digital cameras, cellphones, electric bicycles, flashlights, GPS trackers, drones and even a cordless drill catching fire or overheating on passenger planes. This month the F.A.A. issued a warning that lithium-ion batteries in a cargo hold carry the “risk of a catastrophic hull loss” on an airplane, and that a test conducted last year by the agency found that a lithium battery fire could lead to a catastrophic explosion. The F.A.A. has suggested that airlines perform their own safety-risk assessment and follow a list of agency guidelines.

Especially troubling is that these battery explosions can happen without warning. A study performed last year by chemical engineers at University College
London found that a faulty battery can go from normal to explosive in milliseconds. Battery specialists have warned about explosions for a long time. 

Jay Whitacre, professor of materials science and engineering at Carnegie Mellon University, told Wired magazine last December, in an article titled “Why Hoverboards Keep Exploding,” that consumers should avoid cheap knockoffs from Chinese manufacturers because of inferior battery components that can easily blow up.

The problem of exploding hoverboards is serious enough that hoverboards have been banned from college campuses, airlines and subways and buses in New York. The Consumer Product Safety Commission sent out a stern letter this month warning that the two-wheeled vehicles “pose an unreasonable risk of fire to consumers.” And fire marshals have issued warnings and tips to minimize the risk. So what can consumers do to protect themselves? First, they should hold manufacturers accountable for fixing defects, as the carmaker Tesla did with its battery problem.

In 2013, after two Tesla cars caught fire, the company discovered that both explosions were a result of sharp or heavy objects piercing the battery, which sits in the car’s underbelly. In response, Tesla reinforced the car’s underbody with three shields made of aluminum and titanium.
In general, though, the most important step for consumers is not to buy inexpensive gadgets. Most cases of exploding hoverboards and e-cigarettes have occurred with knockoffs made in unregulated factories in China. As the gadget website Wirecutter suggests, choose a hoverboard that is UL-Certified, which ensures that it has gone through extensive tests. (Though the Consumer Product Safety Commission warns that none are completely safe from fire.) You can also pick up something called a hoverboard fire-resistant safe charging bag, to store the board while it charges. The National Association of Fire Marshals also recommends that people avoid leaving devices unattended while they charge. The same rule applies to laptops and smartphones. Always charge them correctly, and unplug power cords when they are not in use.

As for e-cigarettes, buy a brand that has safety mechanisms built into them. Dan Recio, a founder of the electronic cigarette manufacturer V2, said in a statement that his company, “took action against the possibility of electronic issues from the very beginning, with safeguards integrated into our batteries like automatic shut off and smart chargers that prevent overcharging.” So don’t try to save money with a cheap e-cigarette. It could blow up in your face.

18. Nature spotlights deep skepticism about bioenergy with carbon capture and storage
To mitigate climate change, has the planet “gambled its future on the appearance in a puff of smoke of a carbon-sucking fairy godmother”? Steven T. Corneliusen

24 February 2016
http://scitation.aip.org/content/aip/magazine/physicstoday/news/10.
During the Paris climate summit late last year, European policy analyst Oliver Geden’s New York Times op-ed “The dubious carbon budget” warned that “we’re on the verge of repeating the same mistake that led to the financial crisis: relying on economic models that are completely detached from what’s going on in the real world.” With “magical thinking” and “questionable accounting,” Geden charged, climate scientists and economists are “betting primarily” on an unproven solution: BECCS, or bioenergy with carbon capture and storage. As a voice questioning BECCS, Geden isn’t alone in the media, but Nature in particular has been amplifying the warning.

Just before the Paris meeting, Nature’s Jeff Tollefson contributed the news feature “Is the 2 °C world a fantasy?” The subhead cautioned, “Countries have pledged to limit global warming to 2 °C, and climate models say that is still possible. But only with heroic—and unlikely—efforts.” The piece examined the proposition that it’s possible to pull “Earth back from the brink” using the method of driving “emissions into negative territory—essentially sucking greenhouse gases from the skies—by vastly increasing the use of bioenergy, capturing the CO₂ generated and then pumping it underground on truly massive scales.”

Tollefson explained the use of a combination of bioenergy and carbon capture and storage (CCS):

The system starts with planting crops that are harvested and either processed to make biofuels or burnt to generate electricity, which provide carbon-neutral power because the plants absorb CO₂ as they grow. The CO₂ created when the plants are processed is captured and pumped underground, and the process as a whole eats up more emissions than it creates. A consortium sponsored by the US Department of Energy has tested such a system at one facility that produces bioethanol fuel in Illinois, but neither bioenergy nor CCS has been demonstrated on anywhere near the scales imagined by the models.

Tollefson reported that some scientists argue that the 2 °C scenarios “seem so optimistic and detached from current political realities that they verge on the farcical.” He continued:

Although the caveats and uncertainties are all spelled out in the scientific literature, there is concern that the 2 °C modelling effort has distorted the political debate by obscuring the scale of the challenge. In particular, some researchers have questioned the viability of large-scale bioenergy use with carbon capture and storage, on which many models now rely as a relatively cheap way to provide substantial negative emissions. The entire exercise has opened up a rift in the scientific community, with some people raising ethical questions about whether scientists are bending to the will of politicians and government funders who want to maintain 2 °C as a viable political target.

Just after the Paris meeting, Nature published a commentary by Kevin Anderson, deputy director of the UK’s Tyndall Centre for Climate Change Research. He praised December’s Paris climate agreement as the 21st century’s equivalent to “the victory of heliocentrism over the inquisition,” but warned that “it risks being total fantasy.” He insisted that what’s required is “urgent and significant cuts in emissions.” He lamented, though, that “rather than requiring that nations reduce emissions in the short-to-medium term, the Paris agreement instead rests on the assumption that the world will successfully suck the carbon pollution it produces back from the atmosphere in the longer term.” He cautioned that a “few years ago, these exotic Dr Strangelove options were discussed only as last-ditch contingencies. Now they are Plan A.”
Anderson’s final paragraphs escalated in tone to an outright bitter ending:
The allying of deep and early reductions in energy demand with rapid substitution of fossil fuels by zero-carbon alternatives frames a 2 °C agenda that does not rely on negative emissions. So why was this real opportunity muscled out by the economic bouncers in Paris? No doubt there are many elaborate and nuanced explanations—but the headline reason is simple. In true Orwellian style, the political and economic dogma that has come to pervade all facets of society must not be questioned. For many years, green-growth oratory has quashed any voice with the audacity to suggest that the carbon budgets associated with 2 °C cannot be reconciled with the mantra of economic growth.
I was in Paris, and there was a real sense of unease among many scientists present. The almost euphoric atmosphere that accompanied the circulation of the various drafts could not be squared with their content. Desperate to maintain order, a club of senior figures and influential handlers briefed against those who dared to say so—just look at some of the Twitter discussions!
It is pantomime season and the world has just gambled its future on the appearance in a puff of smoke of a carbon-sucking fairy godmother. The Paris agreement is a road map to a better future? Oh no it’s not.
In a 10 February editorial, Nature’s editors continued raising the BECCS alarm. They characterized interest in it as a fad, cited Anderson’s deep skepticism, and directed readers’ attention to a Nature commentary in which environmental scientist Phil Williamson, as the editors put it, “takes a hard look at some of the questions that BECCS seems to pose, and finds few answers.”
They summarized some of Williamson’s questions:
- How would we preserve forests and grasslands, faced with such a demand for energy crops? How much carbon would be released during the agricultural stage?
- How much water will we need, and where will we get it? How much will it cost to build the network of compressors, pipes, pumps and tanks that will be needed to liquefy and transport the separated CO₂? Can it even be separated at a sensible cost?
Williamson argued that it’s time “to invest in new, internationally coordinated studies to investigate the viability and relative safety of large-scale CO₂ removal.” One passage in particular indicted BECCS:
Limiting the global temperature rise to 2 °C, with any confidence, would require the removal of some 600 gigatonnes of CO₂ over this century (the median estimate of what is needed). Using BECCS, this would probably require crops to be planted solely for the purpose of CO₂ removal on between 430 million and 580 million hectares of land—around one-third of the current total arable land on the planet, or about half the land area of the United States. Unless there are remarkable increases in agricultural productivity, greatly exceeding the needs of a growing global population, the land requirements to make BECCS work would vastly accelerate the loss of primary forest and natural grassland. Thus, such dependence on BECCS could cause a loss of terrestrial species at the end of the century perhaps worse than the losses resulting from a temperature increase of about 2.8 °C above pre-industrial levels.
A more fundamental concern is whether BECCS would be as effective as it is widely assumed to be at stripping CO₂ from the atmosphere. Planting at such scale could involve more release than uptake of greenhouse gases, at least initially, as a result of land clearance, soil disturbance and increased use of fertilizer.
In the Times, Geden’s op-ed observed that the “public has taken little, if any, notice” of the BECCS basis for climate planning. In any case, the questions aren’t new. In September 2014, for example, the Nature Climate Change article “Betting on negative emissions” summarized itself this way: “Bioenergy with carbon capture and storage could be used to remove carbon dioxide from the atmosphere. However, its credibility as a climate change mitigation option is unproven and its widespread deployment in climate stabilization scenarios might become a dangerous distraction.”
In January 2016, MIT Technology Review published “The dubious promise of bioenergy plus carbon capture: Climate change agreements rest on negative emissions technologies that may be unachievable.” BECCS questions have appeared in a few other places in the media as well, including at the Guardian. There Geden published a piece based on his May 2015 Nature commentary, whose warning to scientists was encapsulated in the headline and subhead: “Climate advisers must maintain integrity: As global negotiations fail on emissions reductions, scientific advisers need to resist pressure to fit the facts to the failure.” Rather than spread “false optimism” that purports to justify going deeply into emissions debt in hopes of catching up in later decades, Geden urged scientific advisers to “stand firm and defend their intellectual independence, findings and recommendations—no matter how politically unpalatable.”

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Steven T. Corneliussen, a media analyst for the American Institute of Physics, monitors three national newspapers, the weeklies Nature and Science, and occasionally other publications. He has published op-eds in the Washington Post and other newspapers, has written for NASA’s history program, and was a science writer at a particle-accelerator laboratory.

19. Hundred million degree fluid key to fusion
7 MARCH 2016

Scientists developing fusion energy experiments have solved a puzzle of why their million-degree heating beams sometimes fail, and instead destabilise the fusion experiments before energy is generated.

The solution used a new theory based on fluid flow and will help scientists in the quest to create gases with temperatures over a hundred million degrees and harness them to create clean, endless, carbon-free energy with nuclear fusion.

“There was a strange wave mode which bounced the heating beams out of the experiment,” said Zhisong Qu, from ANU Research School of Physics and Engineering, lead author of the research paper published in Physical Review Letters.

“This new way of looking at burning plasma physics allowed us to understand this previously impenetrable problem,” said Mr Qu, a theoretical physicist.

Nuclear fusion of hydrogen into helium is the process that powers stars. It promises a large-scale energy source on Earth, based on fuel extracted from water, and does not create the long-term waste that uranium-based nuclear fission does.

The breakthrough is in magnetic confinement fusion, in which hydrogen is heated until it is a plasma 10 times hotter than the
centre of the sun, and held in place by strong magnetic fields until fusion reactions occur. However, plasma this hot is extremely turbulent and can behave in surprising ways that baffle scientists, at times becoming unstable, and dissipating before any fusion reactions can take place. Mr Qu developed a simpler theory for plasma behaviour based on fluid flow and was able to explain an unstable wave mode that had been observed in the United States' largest fusion experiment, DIII-D.
Collaborator Dr Michael Fitzgerald, from the Culham Centre for Fusion Energy in the UK, said the new method made much more sense than previous brute-force theories that had treated plasma as individual atoms. "When we looked at the plasma as a fluid we got the same answer, but everything made perfect sense," said Dr Fitzgerald. "We could start using our intuition again in explaining what we saw, which is very powerful."
Leader of the research group, Associate Professor Matthew Hole, from ANU Research School of Physics and Engineering said the theory's success with the DIII-D wave puzzle was just the beginning. "It will open the door to understanding a whole lot more about fusion plasmas, and contribute to the development of a long term energy solution for the planet."
Associate Professor Hole said for him the quest for fusion energy went beyond a sustainable planet. "I'm a bit of a Trekky at heart - the only way you are going to travel to another star system is with a fusion reactor," he said.