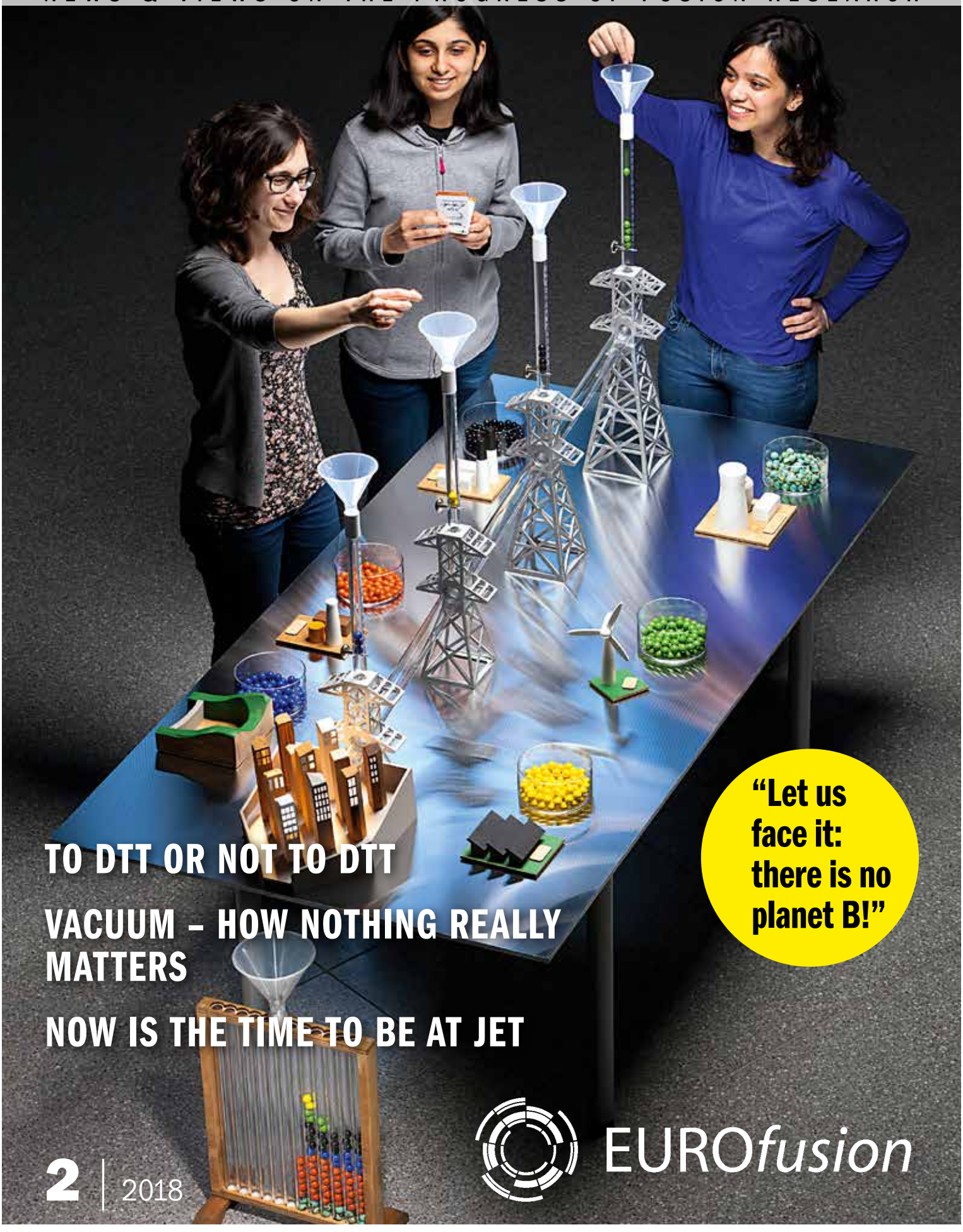
FUSION IN EUROPE

NEWS & VIEWS ON THE PROGRESS OF FUSION RESEARCH



TO DTT OR NOT TO DTT

VACUUM – HOW NOTHING REALLY MATTERS

NOW IS THE TIME TO BE AT JET

"Let us face it: there is no planet B!"

EUROfusion

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EUROfusion | Communications Team | Anne Purschwitz ("Fusion in Europe" Editor)
Boltzmannstr. 2 | 85748 Garching | +49 89 3299 4128 | anne.purschwitz@euro-fusion.org

Application deadline: 25 June 2018

"It is the best time to be at JET right now" says a passionate Eva Belonohy. The member of JET's Exploitation Unit has recently organised a very successful workshop. It was aimed to 'refresh' the knowledge of European fusion researchers regarding the Joint European Torus (JET) but that was a classic understatement. The meeting was a fully-fledged overview on JET's capabilities which have tremendously changed in the past. The tokamak has gone through major upgrades since it saw its first deuterium tritium campaign in 1997. Those include not only an ITER-like wall but also an increase of the heating power by 50 percent. Those are just a few facts which underline the importance of the Joint European Torus as the world's most developed fusion experiment. The tokamak, located in Culham, England, is currently still the only one able to operate with the 'real' fusion fuel …. and presumably will be until ITER starts operating DT in 2035.

The renowned magazine 'Nature' has acknowledged the singularity of JET in an editorial in May this year pushing, between the lines, for funding after 2018 so that the planned European experimental campaign can still be carried out, although 'Brexit' is glooming.

Then there are the catchy claims of fusion start-ups which promise to achieve fusion energy within the next 15 years. Our 'Fuel For Thought' author Scott L. Montgomery addresses those, among other challenges in fusion research, in his article 'Wealth and Needs'. The advocate for fusion speaks out for an improved funding policy.

EUROfusion's approach is stepwise. Its roadmap follows scientific milestones along the road to fusion power and, moreover, defines what happens after ITER – namely DEMO, the first demonstrational fusion power plant. DEMO requires a lot of preparation, tests and pilot studies as well as new research sites, for instance the Divertor Test Tokamak (DTT) facility. But it will be at the earliest in 2022 when the consortium decides about funding this new experiment.

In the meantime, Fusion in Europe highlights the seemingly little research steps that, in the end, change a big machine. Such as ITER which is about to modify some valves thanks to the latest simulations of Wei Zhang. The postdoc, located at IPP Garching, has received the prize of the European Physical Society for his ITER-changing study. Indeed, he follows the European approach when asked about his secret of success: "Set yourself small goals and you will succeed."

EVA BELONOHY

… is satisfied. She organised a highly welcomed workshop which informed about JET's latest upgrades, diagnostics and immense capabilities. 120 out of 150 European researchers participated. This tells a lot about the eagerness towards the upcoming deuterium tritium campaign in Culham.

WEI ZHANG

… is wise. His findings have led to a change in ITER's vessel. Fusion in Europe introduces him as one of the winners of this year's EPS prize. Picture: EUROfusion

CHIARA BUSTREO

… tries looking into people's heads. She leads EUROfusion's Social Economic Studies (SES) team which discovers what society today thinks about fusion energy. Picture: EUROfusion

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NEW

EUROfusion Homepage!

Check out our revamped EUROfusion website! It offers an amazing explainer video and breath taking photographs. The responsive design also allows you to smoothly browse through it with your mobile.

www.euro-fusion.org

The game "Megawatts &Marbles" demonstrates how different types of power generation behave and how they should be balanced. Electricity, represented by marbles, is transmitted down a track to the consumers – a model city. Competitors can try it now at the Max Planck Institute for Plasma Physics. Picture: IPP, MUOVE. DESIGN Jens Mueller, www.muove.de

Moving Forward

News

Philippe Mertens (FZ Juelich) is checking a divertor. Heat exhaust systems play a major role in EUROfusion's programme. Picture: EUROfusion

JET's refresher course delivered a fully-fledged overview about the machines' latest features. The interest to attend was high. Picture: Copyright protected by the United Kingdom Atomic Energy Authority

Hans van Eck discusses the world record of material exposure to fusion conditions. Picture: EUROfusion

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EUROfusion
Programme Management Unit – Garching
Boltzmannstr. 2
85748 Garching / Munich, Germany
phone: +49-89-3299-4128
email: anne.purschwitz@euro-fusion.org
editor: Anne Purschwitz

Subscribe at newsletter@euro-fusion.org
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Workers place together parts of ITER's vacuum vessel. The engineering of suitable vacuum conditions also relies on a close industrial partnership. Picture: F4E

This is the latest fusion experiment in Europe, and probably gone by now: Roger. It comes with a liquid chocolate divertor and was built in Eindhoven. Picture: TU/e

Karl (left) and his dad Bernard call themselves 'fusion geeks'. Bernard played a part in setting up the predecessor of ASDEX. His son Karl has returned to pursue his PhD. Picture: private

Philippe Mertens from Forschungszentrum Juelich is checking the solid tungsten lamellae on a divertor. The divertor is deals with immense heat loads in fusion experiments. Picture: EUROfusion

TO DTT OR NOT TO DTT, **THAT'S THE QUESTION**

The plasma of the first demonstrational fusion power plant will produce heat fluxes alike those on the soil below a starting rocket. Hence, EUROfusion is bound to find the exhaust system which seems the most promising for this harsh environment. Last year, EUROfusion has already granted six proposals to study different approaches Ultimately, the most promising solution should be tested under DEMO conditions in a Divertor Test Tokamak (DTT).

For EUROfusion, the optimum moment to make a decision on funding a Divertor Test Tokamak would be around 2022/2023 when the results from the pilot studies should be available. However, this is not compatible with the more aggressive time schedule proposed by ENEA. EUROfusion's Italian Beneficiary has recently announced that most of the funding for the 500 million Euro project is secure and that Frascati has been chosen as the location for their DTT.

DECISION AT A LATER STAGE

"We are very happy for our Italian colleagues, but as EUROfusion we do not step in the project now. We'll make that decision at a later stage", Tony Donné states. "Building such a complicated super-conducting machine for a budget of 500 million Euro in five years' time is an enormous challenge. Before we take a decision we want to assure that the remaining risks to completion of the project are small."

EUROfusion's highest decisive body, the General Assembly, has agreed to reserve an amount of 60 million Euro as financial support for DTT in the next framework programme. When it considers the remaining risk to completion of DTT small enough it will commit the funding. Around that time it will also decide about which type of alternative exhaust solution should be tested in Frascati. Until then, DTT will be fully under Italian responsibility and EUROfusion will only have a keep-in-touch activity via the ongoing collaboration. ■

EUROFUSION TAKES OVER EIROFORUM PRESIDENCY

In July, EUROfusion is taking over the EIROforum Presidency. EIROforum combines the resources, facilities and expertise of its eight members (CERN, EMBL, EUROfusion, ESA, ESO, ESRF, European XFEL and ILL) to exploit European science to its fullest potential. Moreover, it reaches out to industry to foster innovation and promotes science to teachers, also through their own magazine 'Science in School'. The publication encourages young people to explore scientific subjects and pursue a career as researchers. EUROfusion will follow EMBL in their Presidency for a duration of twelvew months. .

The Directors-General assembly met 2016 at the Paranal Observatory (ESO) in Chile. Picture: Mark McCaughrean (ESA)

www.eiroforum.org

SPIDER STARTS CRAWLING

Bernard Bigot, ITER's Director General, just switched on the largest Ion Beam Source in the world. Its name: SPIDER; which stands for 'Source for Production of Ion of Deuterium Extracted from Radio frequency plasma'. Its job: to test the heating capabilities for ITER. Its location: Padova, Italy.

Switching on SPIDER was the impressive final of a decade of research and manufacturing and the result of excellent collaboration between Consorzio RFX, Fusion For Energy (F4E), European companies, laboratories, ITER India and ITER Organization. Johannes Schwemmer, Director of F4E, argued that SPIDER has built a bridge between business and science.

Representatives of Consorzio RFX, F4E, ITER Organization, ITER India, European and Italian authorities getting ready to launch the first SPIDER plasma. A screen behind the VIPs on stage shows the control room. Picture: Fusion For Energy

Watch what makes this SPIDER so unique:

www.youtube.com/watch?v=oh54L0ZcA5I

Exciting times ahead for JET! To exploit JET's second deuterium – tritium (DT) campaign to the fullest; EUROfusion scientists participated in a "JET Refresher Course". A lot has happened in and around the tokamak since its first DT campaign in 1997. But the success of the machine does not only rely on the technics.

IT IS THE BEST TIME TO BE AT JET RIGHT NOW!

Eva Belonohy, organiser and part of JET's Exploitation Unit, discussing details with Pedro Carvalho.

JET's refresher course delivered a fully-fledged overview about the machines' latest features. The interest to attend was high. Pictures: Copyright protected by the United Kingdom Atomic Energy Authority

> ***"What is also important is the hand-over from one generation to the other."***

"Right now, it is the best time to be at JET", says Eva Belonohy who is part of JET's Exploitation Unit. What Eva and the JET team are preparing for is the most anticipated experimental campaign in fusion research ever. Since the European tokamak is still the only device currently able to carry out a fusion experiment with the 'real fusion fuel', it is one rare occasion for a scientist to be right on the spot when the experiments are about to happen.

A POWER NOT YET SEEN

The new 100% tritium and DT campaigns are scheduled for 2019 and 2020 but the preparations have been going on for years in order to get the most out of it. "Imagine how much has changed since 1997 when JET saw the first DT campaign", Eva explains. She is not only referring to real-time networks or enhanced heating power and diagnostics, but the ITER-like wall, made out of beryllium and tungsten instead of carbon, will have to face a fusion power output not yet seen on tokamaks.

This was all presented during the "Refresher Course". "You could tell from the number of participants that the interest was very high", Eva says. Out of 150 invited international scientists, 127 made the way to Culham for the training. "People say that they were really excited to learn further about JET's immense capabilities. Now, they have time enough to develop the experiments", Eva adds.

PASSING THE TORCH

JET is called 'little ITER' for a reason, especially when it comes to training staff. "What is also important is the hand-over from one generation to the other", she explains. "The people that have witnessed and carried out the first DT experiments at JET will retire before the first tritium campaigns in ITER which are expected in 2035."

A BIG THANK YOU

The important transfer of know how would not be possible without the operational staff in the control room and behind the scenes. "We owe these people so much. They supply us with exciting plasma discharges and plenty of data to analyse", Eva says. Xavier Litaudon, Head of the ITER Physics Department, adds: "We recognise the contribution made by every member of the JET control room team as extremely valuable for achieving JET's scientific results. Their hard work, focus and dedication greatly enhance our efforts to achieve the scientific and technical objectives of the experiments in support for ITER!" ■

LONGEST EXPOSURE OF MATERIAL TO FUSION CONDITIONS

The latest world record in fusion research comes from The Netherlands. Operational since 2017, Magnum-PSI at DIFFER (Dutch Institute for Fundamental Energy Research) has set a new record for the longest exposure of a material to the harsh plasma conditions in a fusion device. Magnum-PSI exposed tungsten wall components to the equivalent of a full year of high power fusion operations in the future ITER reactor.

"VERY IMPRESSIVE"

"I am very pleased to see Magnum-PSI working so well", says Greg De Temmerman. ITER's Coordinating Scientist for plasma wall interactions participated in the experiment. He also provided the small but realistic tungsten mock-ups. The most important task was achieving the right fluence, meaning the total particle impacts per surface area. "The fluence reached by Magnum-PSI is equivalent to that expected during a full year of high power

> *"The fluence reached by Magnum-PSI is equivalent to that expected during a full year of high power fusion operations in ITER."*
>
> *Hans van Eck, DIFFER's facility manager*

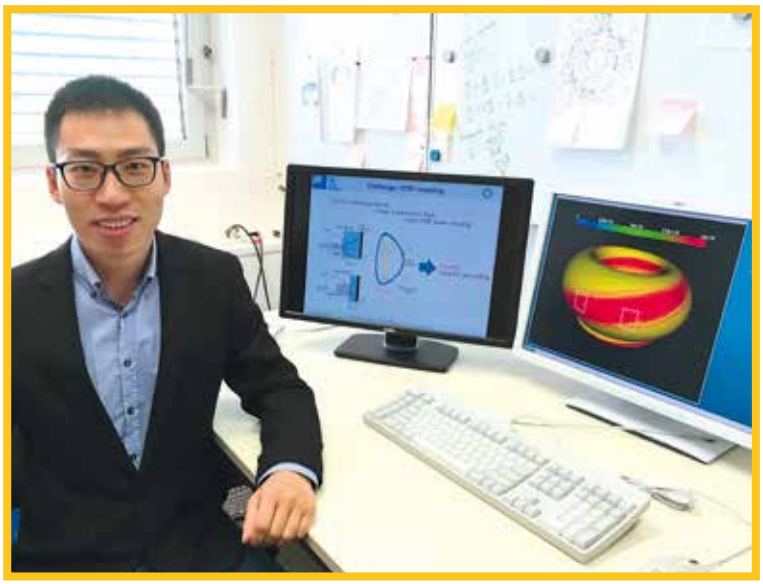
The linear plasma generator Magnum-PSI at EUROfusion's Dutch Research Unit DIFFER. Pictures: EUROfusion

> ***"We will gain the first detailed look into how ITER's wall materials will evolve during their lifetime in the reactor, something no other experiment is able to investigate."***
>
> *Thomas Morgan, Head of DIFFER's plasma research*

fusion operations in ITER. That is very impressive. The previous record, at a different facility, exposed materials to an equivalent of five ITER days", he says and DIFFER's facility manager Hans van Eck adds proudly, "This experiment was really a test of the facility; we'd never gone to such long exposures before. In only 18 hours we exposed a set of tungsten blocks to a fluence of 1030 impacts of deuterium ions per square metre of material, at a power load of at least ten million Watts per square metre". Deuterium is a heavier isotope of hydrogen and forms one half of the fusion fuel mix.

Now, Thomas Morgan, who heads DIFFER's research into plasma material interactions, looks forward to analysing the results: "We will gain the first detailed look into how ITER's wall materials will evolve during their lifetime in the reactor, something no other experiment is able to investigate." ■

***Magnum-PSI** mimics the harsh plasma conditions expected in ITER's exhaust system. These conditions are comparable to a welding flame, a space craft's re-entry heat shield, or at the surface of the sun. Due to these unique capabilities Magnum-PSI is one of the most important experiments for fusion material testing in Europe and, hence, part of the EUROfusion programme.*



Wei Zhang is the author of a study which has been awarded with the Prize of the European Physical Society. Picture: IPP

AWARD WINNER WEI ZHANG AND HIS CONTRIBUTION TO ITER

This prize strongly encourages me to keep up my work in fusion", says Wei Zhang. The postdoc, currently located at the Max Planck Institute for Plasma Physics in Garching, is proudly referring to the prize of the European Physical Society (EPS). Together with Matteo Falessi (Roma Tre University), Jack Hare (Imperial College London) and Adrien Leblanc (University Paris-Saclay), he is one of this year's awardees.

THE PLASMA'S EDGE

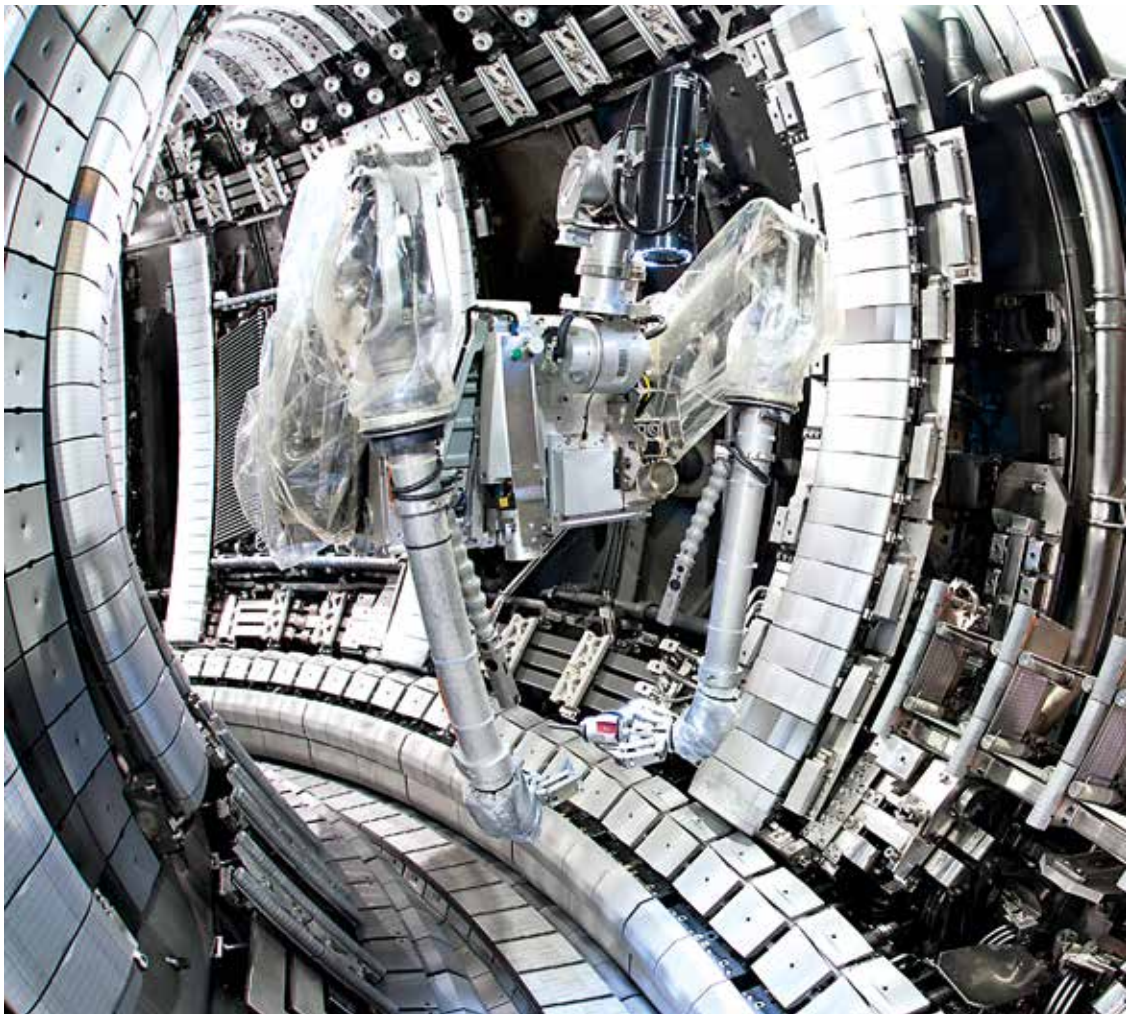
Wei's winning study is called "Plasma edge modelling with ICRF coupling", and one of his studies is improving the ICRF **(Ion cyclotron resonance frequency)** power coupling with local gas fuelling. This investigation is about producing an appropriate local edge plasma density, which then facilitates a good radio frequency power coupling and a proper plasma heating. This solution had already been tested at ASDEX Upgrade and the Joint European Torus (JET) but lacked upscaling for large tokamaks like ITER.
In the end, Wei's modelling for ITER suggested that its local gas valve should be positioned at a different location. "Originally, they had planned to put four gas valves on the outer top of the vessel of the tokamak. Since, based on my calculations, I could prove that midplane gas valves close to the antenna would be much better to increase the local plasma density and the ICRF coupling , the location of one of the valves was now switched to the midplane", explains the 29 year old Chinese.

MENTORING MATTERS

Wei is now looking forward to present his work at this year's EPS conference in Prague. Receiving awards is the one thing that reassures him, the other side is the prospects of realising fusion: "Fusion research is tough but in the end it will lead, without a doubt, to the most sustainable source of energy for mankind", he says. Wei wants definitely to continue in fusion and calls himself happy to rely on good mentors as well. "If I am stuck in my work or I do not know which path to follow, I can always go and ask for advice. Not only for my research, by the way, also in life", he says smilingly.
The prize winner has advice for students who are currently thinking of following his way into a career in fusion science, which might reveal the secret of his own success: "We should take on the challenge of achieving fusion power stepwise: "Set yourself small goals and you will succeed."

> *"We should take on the challenge of achieving fusion power stepwise: Set yourself small goals and you will succeed."*

VACUUM – OR – HOW NOTHING REALLY MATTERS



Many people mistakenly think that vacuum equals nothing. In fact, in fusion a high vacuum is crucial to keep the reaction going. To realise those conditions, research relies on practical applications from industrial partners. Supplier Leybold has delivered solutions on Wendelstein 7-X, ASDEX Upgrade, JET and ITER. The company claims that the engineering can be fixed, but there is still a complex tender to be won. This is about to improve for EUROfusion.

Inside JET's vacuum vessel. A Remote Handling Gripper solves maintenance tasks. Picture: EUROfusion

VACUUM

is space free from matter and highly desired inside the vessel of a fusion experiment. Impurities, particularly heavy gases, cause the plasma to cool down rapidly and stop the reaction. Other gases such as oxygen may react with the machine lining.

PUMPING OUT PARTICLES

The vessel of each fusion experiment needs to get rid of unwanted particles before, during and after the reaction through special pumps. It is not only the amount that is important. Also, regulations matter since tritium and beryllium dust, from the fuel, are toxic and tightly regulated.

The pumping system must be absolutely reliable. Finding leaks in a maze of pipes takes long and reduces precious experimental time.

ITER'S HANDBOOK ON VACUUM

ITER's experts have released their own vacuum handbook. About 300 pages show the importance of a proper vacuum system. Nothing matters! And this is just the theory. In order to turn it into practice, science can partly rely on practically experienced industrial partners who know about harsh conditions as well as a proper licensing process. Sometimes the cooperation with those partners lasts for decades in order to jointly develop solutions for big one-of-a-kind fusion experiments.

'OFF-THE-SHELF' WON'T DO

"We do not pull out the answers from our drawer. So we are continuously exchanging with fusion researchers", says Petra Endrös. She is in charge of High Vacuum Systems at the company Leybold, one of the global players in vacuum technology.

> ***"We do not pull out the answers from our drawer. So we are continuously exchanging with fusion researchers."***
>
> *Petra Endrös, Business Line Manager High Vacuum Systems, Leybold*

> ***"What matters more than 'off-the-shelf' offers from industrial all-rounders are one-of-a-kind solutions which are especially tailored for fusion – and, moreover, our research and development must be inherited here."***
>
> *Christian Day, Project Leader of Work Package Tritium-Fuelling-Vacuum in the EUROfusion DEMO Programme*

"What matters more than 'off-the-shelf' offers from industrial all-rounders are one-of-a-kind solutions which are especially tailored for fusion – and, moreover, our research and development must be inherited here", says Christian Day who oversees the pre-conceptual design of the vacuum systems for DEMO within EUROfusion's Power Plant Physics and Technology Department.

Workers place together parts of ITER's vacuum vessel at Walter Tosto. Picture: Fusion For Energy

TURNING THEORY INTO PRACTICE

Still, fusion does not play the main part in Leybold's projects. Due to the highly specific requirements, the long-time investments and the hurdles of publicly funded research, tokamaks and stellarators maintain a rather minor role. Leybold also delivers pump systems for the process industry, the coating technology (used, for instance, in displays) or the Space and Defence sector. CERN too belongs to their clients. Nevertheless, the variety of fields is a benefit for fusion.

OFFERING PUMPS AND PROJECT MANAGEMENT

"We do not only offer solutions but we can surely help to apply a suitable project management and to define the milestones", Petra Endrös adds. According to her experience, it can be sometimes challenging to win a contract with public research institutions. While discussing the concept of a tokamak's upgrade or even a new device, the company invests time, manpower and, in the end, a lot of money prior to any payment. "Our CEOs look for profit, not so much for soft skills", she says.

THE COMPLEX TENDER PROCESS

It can be very hard to come up with the ideal solution and, after this, being forced to wait until the complicated tender process is won, an obligation which applies to all projects in the public service. This request forces private companies to bid in order to deliver their products. This administrative step aims to ensure that the competition for the use of public funds is open, fair and free from bribery and nepotism. "It feels like those tenders become more and more complex. It's not so much about references which we also have to provide extensively; we just have to deliver a lot of paperwork. This takes time, requires special knowledge in business law and still, we won't know by then that we will see any money", Endrös says.

> *"We benefit from the industrial experience in the design so that we include the correct licensing, manufacturing and operational aspects for DEMO at a very early stage."*

Gianfranco Federici, Head of the Power Plant Physics and Technology Department.

HELP IS ON THE WAY

EUROfusion is seeking to increase its relationships with industry and therefore aims to simplify such processes. "We want to benefit from the industrial experience in the design so that we include the correct licensing, manufacturing and operational aspects for DEMO at a very early stage", says Gianfranco Federici, Head of the Power Plant Physics and Technology Department.

"With the support of the European Commission it is very likely that, next year already, we will have a new framework tool which will speed up our negotiations with companies. With this, we will be able to contract industrial partners not, like usual, within the scope of five to six months but in few weeks only."

The word stems from the Latin adjective *vacuus* for "vacant" or "void". An approximation to such vacuum is a region with a gaseous pressure much less than atmospheric pressure. **Gas pressure below 50 mbar is considered a 'vacuum'.**

Zugspitze, Germany
2.962 m
705 mbar

Zuspitze as seen from Alpspitze Picture: Creative Commons/Christian Nawroth

Mont Blanc, France &
4.810 m
555 mbar

“Establishing long-term partnership with industry is an essential part of our mandate, as we move from present to future fusion projects in Europe – which means, from ITER to DEMO.”

Leonardo Biagioni,
Head of Contracts and Procurement at F4E

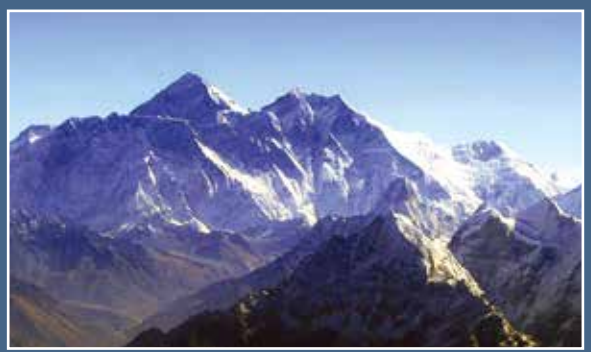
OPEN AND CREATIVE PARTNERSHIP

A strong relationship with industry is already reality in EUROfusion’s sister organization, Fusion for Energy (F4E), which is in charge of delivering the European contribution to the ITER: “Establishing long term partnership with industry is an essential part of our mandate, as we move from present to future fusion projects in Europe - which means, from ITER to DEMO”, says Leonardo Biagioni, Head of Contracts and Procurement at F4E.

This surely applies to project leader Christian Day’s approach: “Partnership is the key! For me, it is most important to ensure an honest, open and creative spirit amongst my team and future industrial partners to exploit our potential to the fullest”, Christian Day sums up. ■

Italy

Mont Blanc
Picture: Creative Commons/Spiridon Manoliu



Mount Everest, Nepal
8.848 m
315 mbar

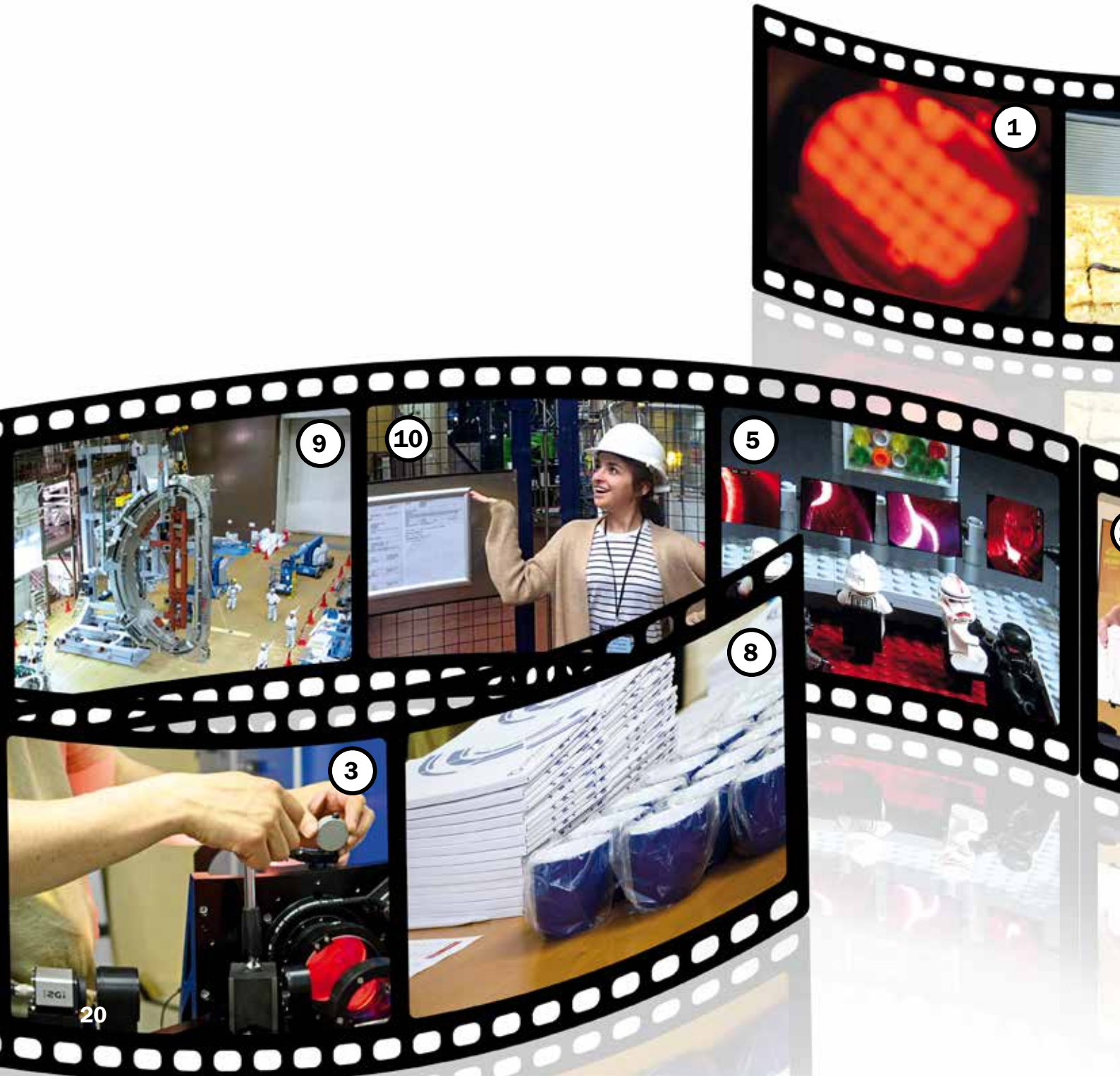
Aerial view of Mount Everest from the south
Picture: Kerem Barut

The Joint European Torus realises a vacuum of 1E-7 mbar which equals 1/10000000 of 1mbar.

This means that if you would stand inside a fusion vessel, a particle would pass you by every five to six minutes. If you would be standing on Mount Everest, where the pressure is already really low for humans, you would still be constantly bombarded by elements.

Impressions

IMPRESSIONS *Impressions* IMPRESSIONS Impressions IMPRESSIONS



1 *Those are diagnostic systems for MAST Upgrade. The spherical tokamak currently undergoes a major upgrade and so do its diagnostics. This one comes from Hungary. Picture: Wigner*

2 *'Roger' was created to celebrate the 50th birthday of Prof Roger Jaspers. Picture" TU/e*

3 *Assembling the Beam Emission Spectroscopy Diagnostics Optics for MAST-Upgrade. Picture: Wigner*

4 *The 340 degree JT-60SA tokamak assembly ready for the insertion of the final sector. Picture: QST*

5 *May the force be with you – also in Culham. Fernanda Rimini shared this picture for Star Wars Day on 4 May. It shows a lot of force in the control room. Picture: F. Rimini*

6 *A Slovenian delegation visiting the ITER site on 25 May with Mr. Bigot. Picture: Slovenian Fusion Association*

7 *This is the latest fusion experiment in Europe, and probably gone by, now: Roger. It comes with a liquid chocolate divertor and was built in Eindhoven. Picture: TU/e 11*

8 *EUROfusion equips its researchers well. The picture was taken ahead of JET's refresh course in Culham. Picture: copyright protected by UKAEA*

9 *Coils in the air. The assembly of JT-60SA in is in full swing. The pre-assembled sector comprising toroidal field coil, final vacuum vessel sector and its thermal shield being lifted for installation. Picture: QST*

10 *"My experience here was a big help in figuring out what specifically I wanted to study in fusion!" says Megan Goodland from Canada who attended the summer school in Culham. Picture: private*

11 *DIFFER's Gieljan de Vries had the audience at his fingertips when illustrating basic principles of fusion with tabletop experiments, such as a regular microwave. Picture: ITER*

12 *Glimpse of the first ITER manga "A small sun on Earth". It is available in Japanese, French and English. Picture: ITER*

13 *Here is a picture of MAST in full view. Picture: SMD*

FUSION IN EUROPE INVITES

Scott L. Montgomery

WEALTH AND NEEDS

Scott L. Montgomery authored the article "Why Nuclear Fusion is Gaining Steam – Again" earlier this year for 'The Conversation', a website which features scientific information for the general public. In his article, Montgomery discusses the trials and tribulations associated with achieving fusion energy on Earth. He talks about scientific and engineering breakthroughs and puts the catchy claims of the latest fusion start-ups into perspective. He also speaks out in favour of increased funding for fusion research. Hence, Fusion in Europe asked him to delve deeper into the topic for us.

If science be our guide and logic our muse, there should never have been much to question about the energy future, except when it might arrive. Taking inspiration from the universe itself, this future would be nuclear. Fission first, since this is far simpler to achieve, with a period of testing and demonstration coordinated amongst several nations, so a choice of best reactor design(s) could be made. Simultaneously, a long-term programme fusion would also be carried out. Efforts here would also be multinational, with some overlap and competition between laboratories. Support would be unquestioned—scientific knowledge would make it clear that this would be a key source for powering human life. How could we do better than the cosmos?

HOW MUCH IS ENERGY WORTH TO SOCIETY?

Of course, this scenario is a dream. It is a dream not because of something called "human nature," but because of dimensions related to history and driven by politics, economics, traditions of conflict and identity, and, not least, by the power of ideas.

How much is energy worth to society? Today, we have a system of extracting and using fossil fuels valued about $30 trillion dollars. Add to this, another $2.5 trillion for 450 fission re-

actors and a bit more on top for hydropower. Since 2000, a sum of nearly $4 trillion has been invested in wind and solar power, propelled by concerns about climate change. The total sum therefore seems vast. Yet it is less than the combined Gross Domestic Product of the five richest nations for one year, 2017. The US alone was at $18 trillion. In short, there is no lack of wealth to invest in energy systems to power the modern world.

THE TALE OF WIND AND SOLAR …

… might seem like a real-life version of the dream above, except for one thing. These sources harness only epiphenomena of the Sun. Measured in Joules per m^3, they are more than a dozen orders of magnitude less energy-rich than crude oil, itself exceeded a million times by uranium-235. The idea that modern society, whose history has depended on ever more energy-dense fuels (wood to coal to oil/gas to uranium) must be run by immensely weaker sources is therefore not merely wrong, but a reversal of history. We do need them, as we will need fission, as non-carbon entries. But they are no endpoint. If we wish to draw power from the Sun, atmospheric phenomena won't suffice when the real thing beckons with possibility.

Nonetheless, the world's richest nation, along with some others, wants energy progress on the cheap. Despite spending innumerable billions of dollars on technologies to annihilate armies, navies, cities, and nations, the US Congress foams with debate over investing just a few million in research that could make the world more secure.

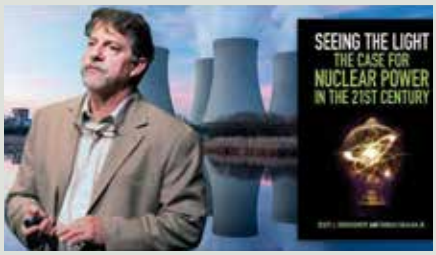
ITER'S CURRENT PRICE-TAG

The EU covers about 45.6% of the construction costs for ITER, currently the most advanced fusion effort, while the US, China, India, Russia, Korea, and Japan are each responsible for 9.1%. To the interested observer, whatever negotiations might lie behind these numbers, under a tenth can't qualify as a serious commitment for the US.

The total cost for ITER is now estimated in the realm of $25 billion. While much complaint and critique have been aimed at growth in this figure, we might note that ITER is the first of its kind anywhere and involves many hundreds of component providers from a variety of nations. The risk of higher costs was always present. Further, its current price-tag is equalled by a single dam in China and fully doubled by just one LNG plant recently completed in Australia. Much beerhall enthusiasm greeted the news that America's contribution to ITER, after being halved in 2017, was doubled for 2018 and so keeps the project on schedule. Since formation of the ITER Organization in 2007, the US has devoted roughly $90 million per year to the project.

ENERGY ON THE CHEAP?

Ideas that have largely influenced the US federal budget since the 1980s argue that it is markets that will build the energy future, not government support. This situation has helped contribute towards the emergence of fusion start-up companies, which are entrepreneurial efforts to attract private funding. Some of these start-ups, unfortunately, have felt a need to dispar-



Scott L. Montgomery *is an author, geoscientist, and affiliate faculty member in the Jackson School of International Studies at the University of Washington. He writes and lectures on a wide variety of topics related to energy, including geopolitics, technology, resources, and economics. He is a monthly columnist for Global Policy and has contributed articles and op-eds to many journals such as The Conversation, Forbes, Newsweek, Salon, and The Huffington Post, and has been a frequent commentator for local and national media. His most recent book, written with longtime nuclear arms negotiator Thomas Graham Jr., is Seeing the Light: The Case for Nuclear Power in the 21st Century (Cambridge, 2017).*

age ITER as the wrong model for fusion, due to bureaucracy, red tape, waste, etc. This embrace of anti-government rhetoric is the equivalent to the renewables über alles on the left. It is bad press for everyone in the fusion community. It is also an effect resulting from the climate of pursuing energy progress on the cheap.

The real enemies, in other words, are indifference to the energy future and, where interest exists, miserly commitment. The world is more than wealthy enough to accept what science and logic would advise, which is to warmly support a range of approaches to fusion. Perhaps this will happen. It was Walter Teagle of Exxon, an oil man, after all who once noted it would be better to create the future than be forced to react once it arrived. ■

Link to the article
Why Nuclear Fusion in Gaining Steam – again:

https://theconversation.com/why-nuclear-fusion-is-gaining-steam-again-93775

WE NEED TO ACT NOW!

Picture: EUROfusion/Shutterstock

EUROfusion does not only coordinate fusion energy research. On behalf of the consortium Chiara Bustreo and a team of 17 European experts investigate how society perceives fusion in general. In an interview Chiara explains why we need to put so much effort in the societal aspect of fusion and what society already knows.

Picture: seyfettinozel/iStock

Chiara Bustreo

WHY DO WE NEED SOCIAL ECONOMIC STUDIES (SES)?

We identify what has to be done to allow a smooth integration of fusion into society. Fusion has good chances to be the horsepower in the rush towards clean energy production. But, actions must be taken in advance to accommodate the new nuclear fusion technology along with renewables and other carbon-free power plants. Therefore, we simulate different scenarios for both the world and its energy system.

WHAT ABOUT THE GENERAL ATTITUDE TOWARDS NUCLEAR FUSION?

Social aspects are no less important. We also put great effort in monitoring and understanding the social attitude towards fusion technology in order to identify the factors shaping its acceptability.

WHY IS THE PEOPLE'S OPINION ON FUSION IMPORTANT FOR THE IMPLEMENTATION OF FUSION?

People have the right to decide about their future. Their opinion should be based on extensive and proper information. Gaining knowledge about what people know of fusion and its technology helps us to provide them with the information they need to come to a well-balanced personal opinion. Our team identifies public and stakeholders' beliefs and concerns; so that we can detect controversial aspects or incorrect beliefs about fusion.

WHY DOES SOCIETY HAVE TO BE AWARE OF A TECHNOLOGY THAT COMES AFTER 2050?

2100 is indeed really far away, it's true, but we must consider the inertia of the energy system to changes. Indeed, none of the current power plants will be in operation at the end of this century. For example, it is quite unlikely that future generations will see the cooling towers and chimney stacks of coal-fired power plants. They will see instead a wide land covered by a blanket made of solar panels; or valleys and seas occupied by large wind turbines. Also, the electricity grid will require major updates accommodating the decentralised electricity generation and consumption. If fusion is to be a part of this future energy landscape, we need to act now to create the right conditions for its inclusion. Sudden veers are not allowed in this field!

WILL 2100 BE TOO LATE FOR FUSION ENERGY?

If you mean that fusion is the solution to climate change, yes, fusion will come too late.

Nevertheless I do see fusion as a technology that will deliver large, reliable and constant amounts of carbon-free electricity.
It's quite likely that fusion and renewables are the main actors of the future energy mix mainly because of the public unacceptability of nuclear fission and carbon storage. If this is the case, the role of fusion will be determinant to ensure the energy system reliability weakened by unpredictable and intermittent renewable electricity production.
Bringing fusion online is certainly a challenge but I trust that the scientific community is committed to solve. It is our long-term mission to design a safe and reliable technology which produces carbon free electriwcity for future generations. Nuclear fusion definitely fits the role. ■

"You work with CERN right?"

Results of a study on public understanding of fusion

SES has recently carried out a national survey of awareness in Belgium. The group also contributed to the Portuguese section of the European Social Survey to assess public attitudes towards fusion. In both countries more than 60% of the surveyed do not know about fusion energy. According to the Belgian study, those who had previously heard about fusion were vaguely familiar with the topic. Also, people tend to frequently confuse fusion with nuclear fission or even the CERN particle accelerator. As a follow-up, Chiara's team plans to classify the opinions in other European countries through a pan-European survey. In the meantime, the SES team is modelling new energy scenarios. The results will be published by the end of the year.

Also read the article from Fusion Writer Davide Silvagni regarding the question "Do we actually need fusion energy at all?"

https://www.euro-fusion.org/news/2017-3/do-we-actually-need-fusion-energy-at-all/

Megawatts & Marbles

… is a workshop which allows players to balance out their on mixed energy system with the help of marbles. PhD students at the Institute of Integrated Energy Systems (University of Victoria) have developed this game in which participants experience the struggles of power plants who must work together to meet time-varying demands. Electricity, represented by marbles, is transmitted down a track to the consumers – a model city. Will the generators meet the demand or will the lights go out? The Max Planck Institute currently offers to participate in this workshop. If you are interested, you can get in touch via

Energieplanspiel@ipp.mpg.de

Picture: IPP, MUOVE.DESIGN

Karl Stimmel and his dad Bernard in their basement lab in Michigan. Picture: private

LIKE FATHER, *LIKE SON*

The history of fusion energy is like building a cathedral. The knowledge is passed on from one generation to the next. Sometimes even from father to son. Karl Stimmel is currently pursuing a PhD in fusion at the Max Planck Institute for Plasma Physics in Garching. And in doing so, he follows in the footsteps of his dad who set up the first control system for the cooling of the Pulsator, ASDEX' predecessor, 40 years ago.

Karl Stimmel watching the progress of fusion energy live at ITER in Cadarache, France. Picture: private

> *This is amazing! My father has to see it, ...*

... says an excited young man as he is leaving the auditorium of the Garching Institute for Advanced Studies on this October afternoon. The film Karl Stimmel has just watched was "Let there be light", a Canadian documentary on the 100-year quest for fusion energy. It shows the global efforts of generations across the globe in order to turn fusion energy into reality.

MEASURING THE PULSE

This story affects Karl Stimmel in more than just one way. That is why he is now so eagerly looking forward to introducing the movie to his father. 40 years ago, Bernhard Stimmel, helped to lay fusion groundwork, right here in Garching at the Pulsator. His son Karl has now returned to the successor unit, ASDEX Upgrade, which has since become one of the leading tokamaks for fusion research.

PUNCHING THE PROGRAMME

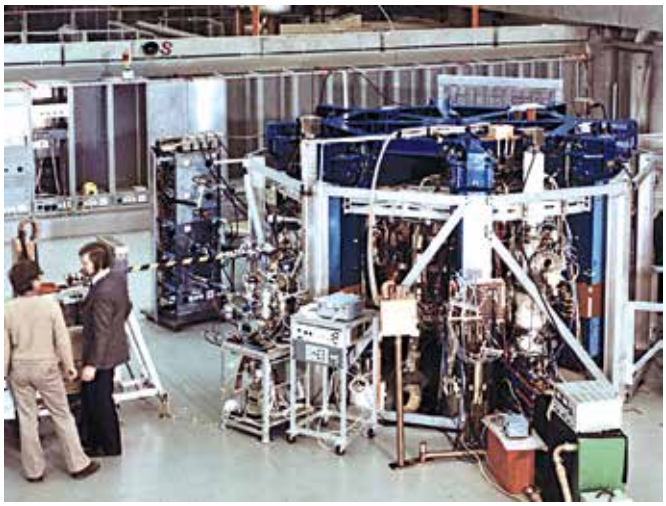
"When I was a child, my dad told me about fusion energy. He has enthusiastically followed the progress of ITER all those years, although he left Germany and ASDEX years ago", says Karl.

> *When I was a child, my dad told me about fusion energy. He has enthusiastically followed the progress of ITER although he left Germany and ASDEX years ago.*

Back in 1978, Bernhard Stimmel founded a small company which was experimenting with the first commercially available microcontrollers. His knowledge proved useful in the installation of a first temperature control system for the new tokamak.

"It had to be programmed by an outside source using punch cards, every byte diligently blackened with pencil bit-by-bit. Overall very ancient technology", Bernhard says. But it obviously did the job, even after the IPP engineers tried to trip it with a high voltage spark generator. "I was really holding my breath", Bernhard remembers.

Finally, in April 1979, Bernhard's system was installed in one of the many electronic cabinets close to the tokamak. "It got tested, and we got paid handsomely we thought", he adds.



The predecessor of the ASDEX tokamak, the Pulsator which was operating from 1973 to 1979. Picture: IPP

> ***"My dad never said, son, you have to pursue a career in fusion. I really liked what he told me about it. I want to work in fusion because I enjoy the idea that it can really help mankind to prevent its own extinction."***

FROM CLASSES TO PRACTICE

"My dad never said, son, you have to pursue a career in fusion. I really liked what he told me about it. I want to work in fusion because I enjoy the idea that it can really help mankind to prevent its own extinction", says Karl.

As an undergraduate student at the University of Michigan, Karl succeeded in creating a tool which converts plasma into sound. It was so successful that it was frequently used as a demonstrational device until there was no one left who knew how to maintain it

Encouraged by his success at university, Karl applied as an intern at the Institute for Plasma Physics in Garching four years ago and managed to build a microcontroller which enables the reliable measurement of plasma density inside the tokamak.

"Everything I had just learned in the classroom had to be put in practice. I worked extremely hard on this, harder than ever before. On my last day, I was in the control room and I pressed the button. My invention actually worked. I was so excited! The best day ever, in summer 2014", Karl admits.

FROM PUNCH CARDS TO SUPERCOMPUTERS

Three years on, Karl has again returned to Garching, this time as a PhD candidate of the Helmholtz School for Plasma Physics. He now simulates plasma turbulence in the Pedestal, the outer region of the Tokamak.

It has been a long journey for the Stimmel family, from the father who once pencilled punch cards in the 1970s, to the son writing computer codes for high performance calculators.

"Dad claims that at this point ASDEX is now over his head but I am really excited to discuss it with him. To me it is so much fun to have someone to geek out on this", Karl adds.

Still, after all this years, Bernhard Stimmel remains a true believer in fusion: "We are getting closer to striking the match to light the self-sustaining star fire on earth. Many people don't see the significance of this effort, but it is crucial for the future of life on earth", he states.

A colleague of Bernard Stimmel, Siegried Schulz, checks out the temperature control system before delivery in 1978. He was responsible for the mechanical aspects of the control system. Picture: private

> ***"We are getting closer to striking the match to light the self-sustaining star fire on earth. Many people don't see the significance of this effort, but it is crucial for the future of life on earth."***

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summing up+

"The facility [JET] itself is ploughing ahead with its preparations […], under the assumption that it will be funded for the next two years. It has no choice but to do so. The planned experiments are key to understanding how plasma will behave in reality, and nowhere else in the world can do the research before ITER is due to begin."

'Brexit uncertainty threatens fusion-energy research'
in Nature 557 (611, 2018), 29 May 2018,

tinyurl.com/yahhwqyc

nature

"Let us face it: there is no planet B."

French President Emmanuel Macron in front of the US Congress in April 2018. Bernard Bigot, ITER's Director General was part of the presidential delegation to Washington. Watch the fiery speech:

youtu.be/XYTx4DrBhzM

Christian Vorpahl.
Picture: EUROfusion

"… we need to work on developing fusion energy now. Only then will we know if fusion can be a viable energy option for the future. Starting work on fusion 20 years from here will be too late and we will be at a point of no return", EUROfusion scientist Christian Vorpahl.

'Der lange Weg zur Kernfusion',
Der Tagesspiegel, 8 May 2018

DER TAGESSPIEGEL

tinyurl.com/y9uj9ylq

EUROfusion

EUROPEAN CONSORTIUM FOR THE DEVELOPMENT OF FUSION ENERGY

REALISING FUSION ELECTRICITY

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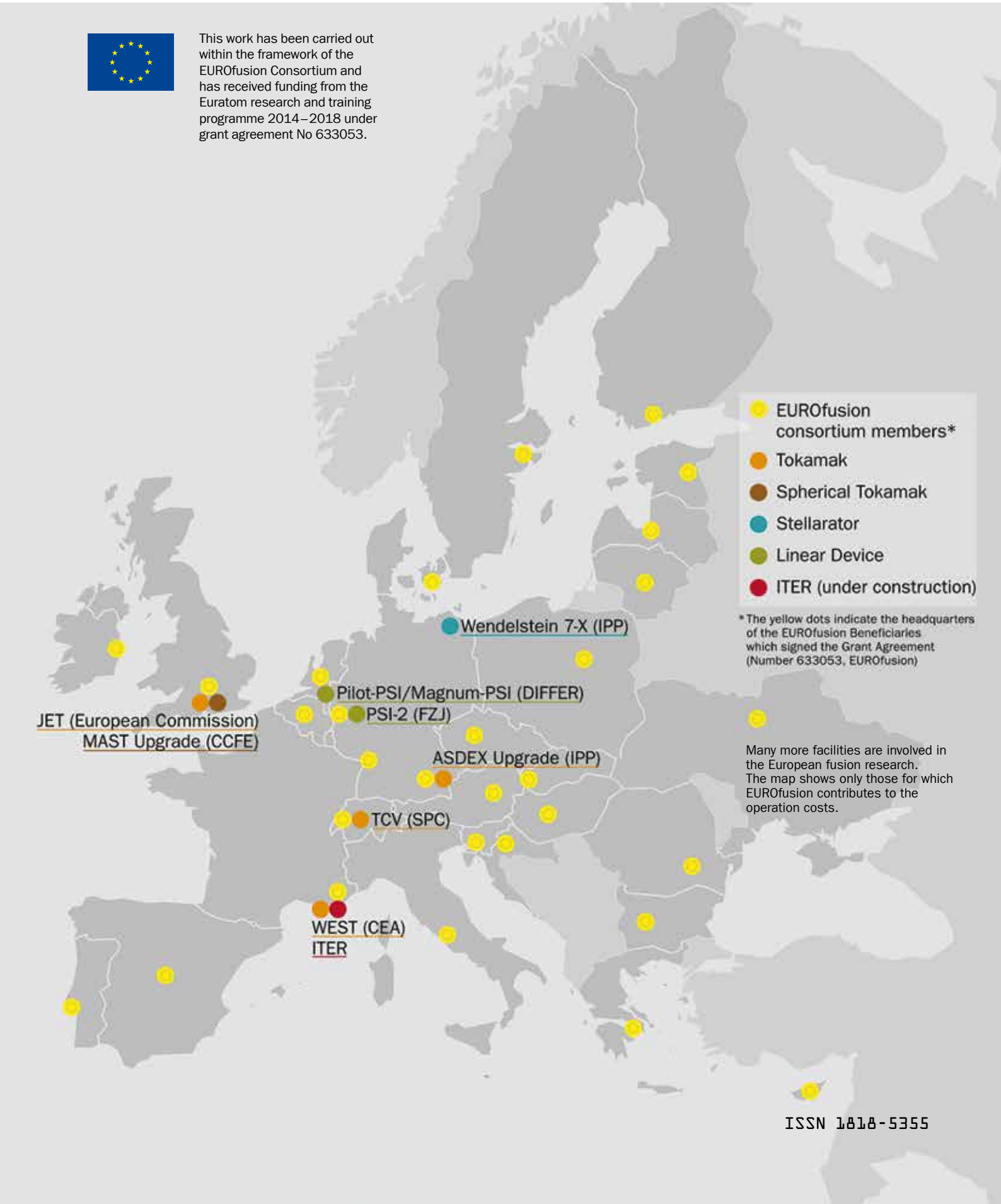

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