HZB BESSY II Light Source

BESSYII@HZB

Synchrotron Light Sources for Building the Global Scientific Community

Antje Vollmer

School on Synchrotron Light Sources and their Applications

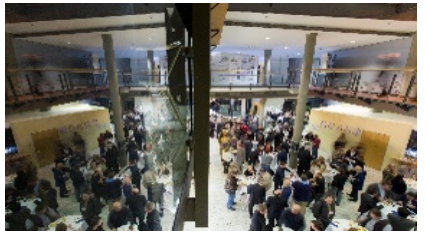
Outline

BESSY II and her sisters in the world

Users and user communities

Challenges and solutions

Beyond brilliant science

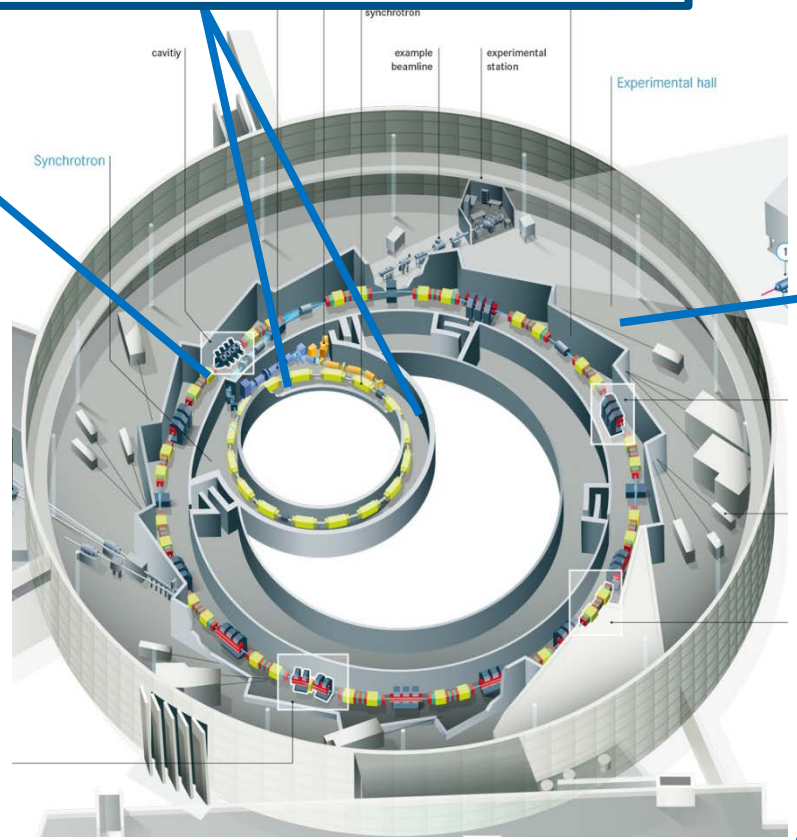


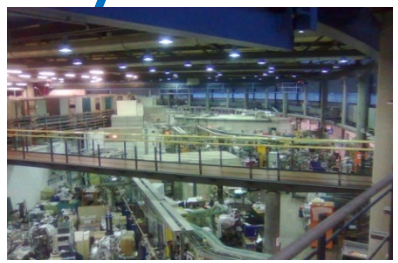
WHAT IS SYNCHROTRON RADIATION SOURCE?

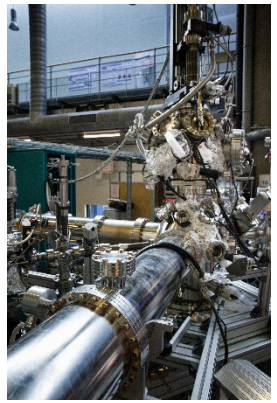
LINAC and Synchrotron

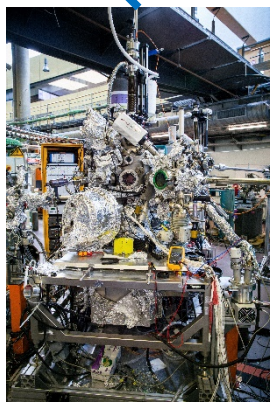
the Storage Ring

Beamline and Experiment

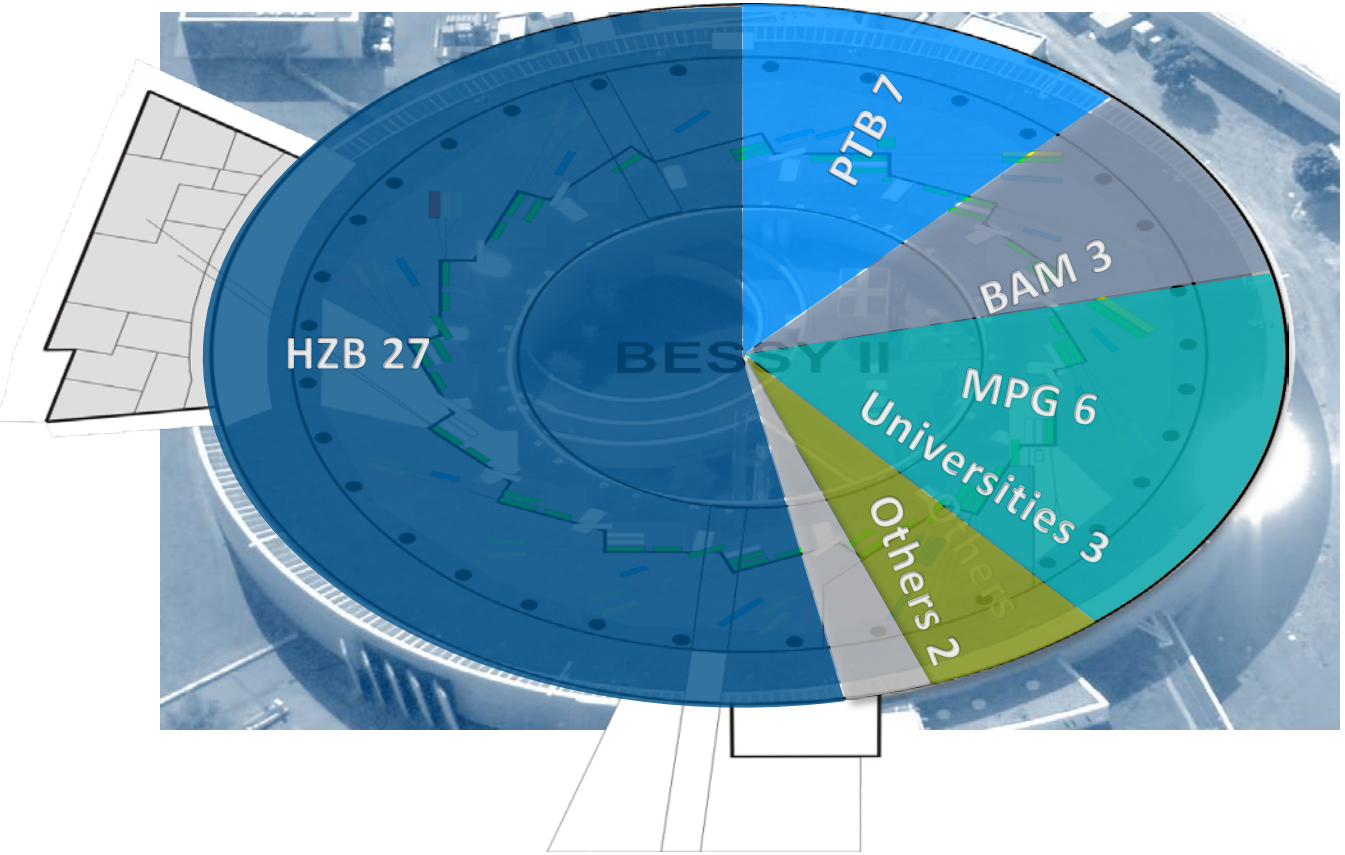


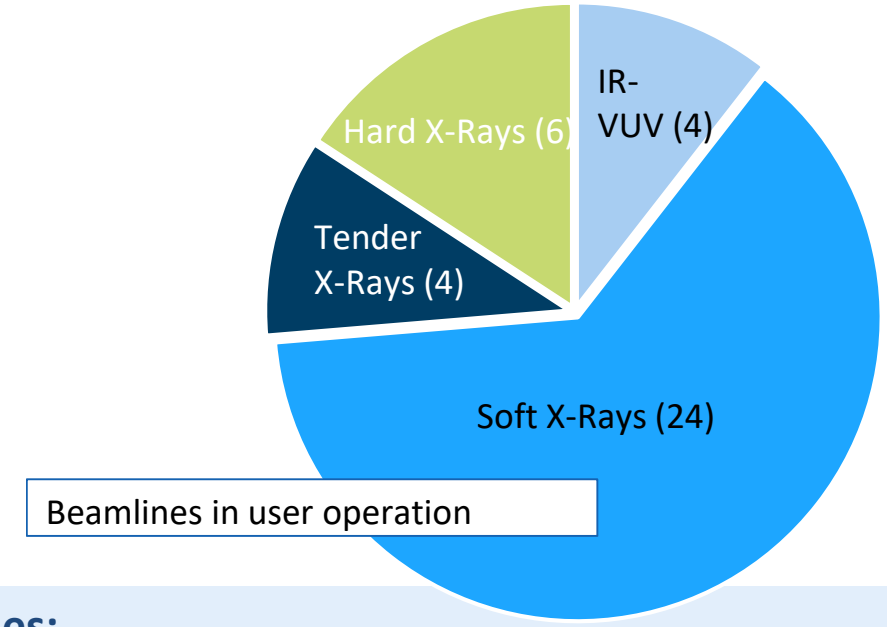






BEAMLINES AT BESSY II





Beamlines:

48 beamlines in operation, thereof

38 beamlines in user operation

→ **BESSY II focuses on VUV to soft X-rays, but we offer radiation fromTHz to hard X-rays**

EU:

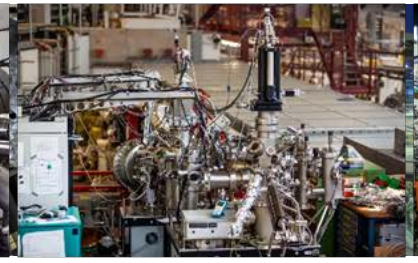
More than 270 Beamlines

More than 6000 beamtime campaigns

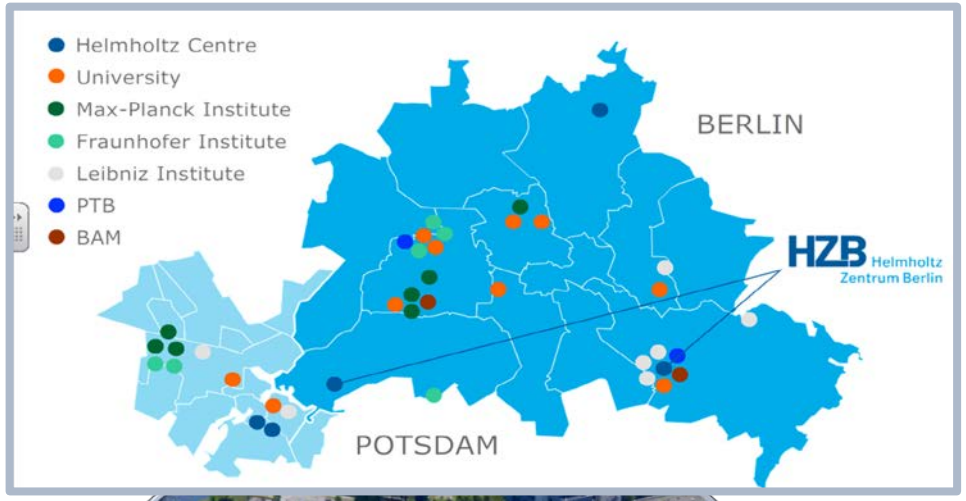
More than 30.000 users

More than 10000 publications






SYNCHROTRONS OF THE WORLD

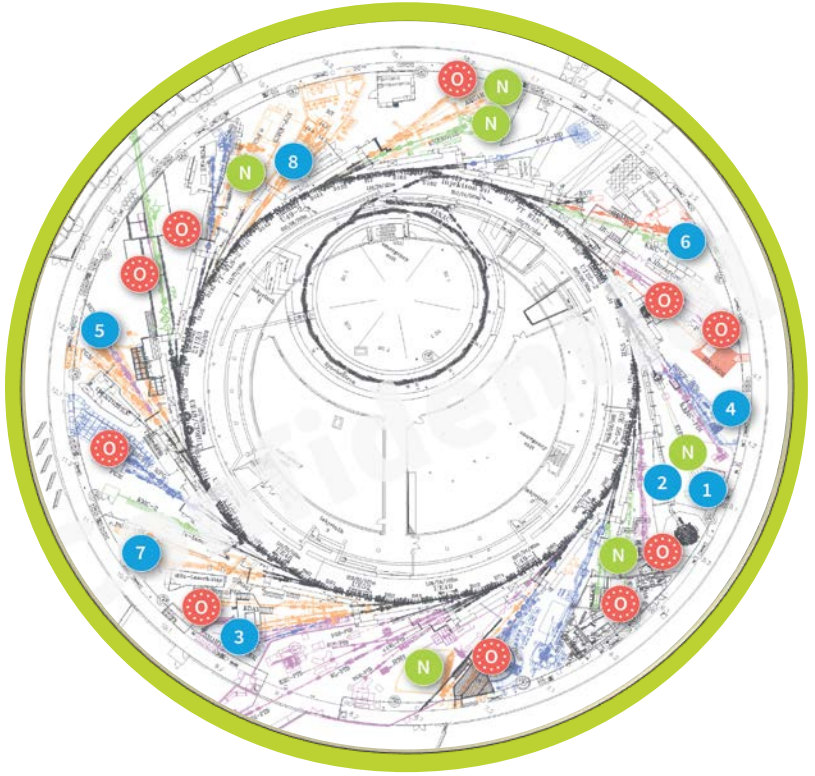


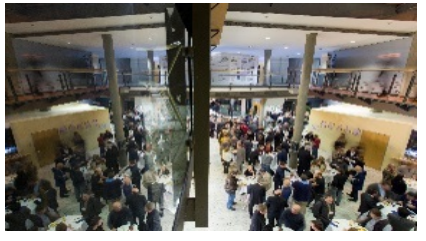
BESSY II and her sisters in the world

Users and user communities

Changes and Challenges

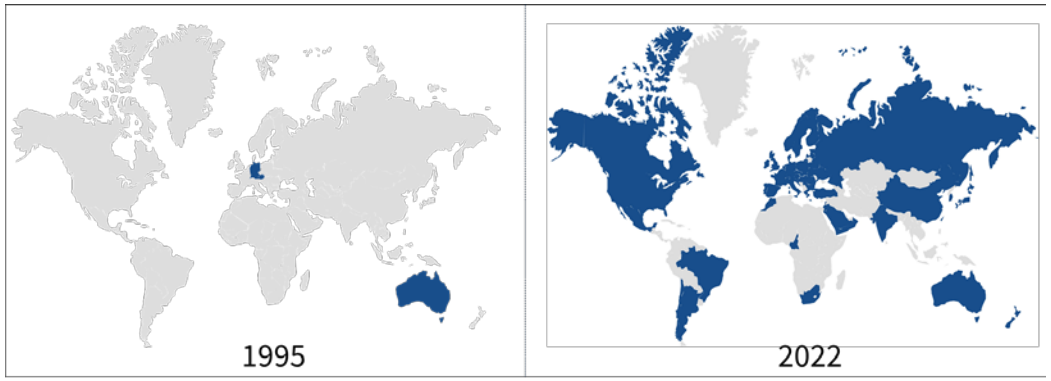
Beyond brilliant science

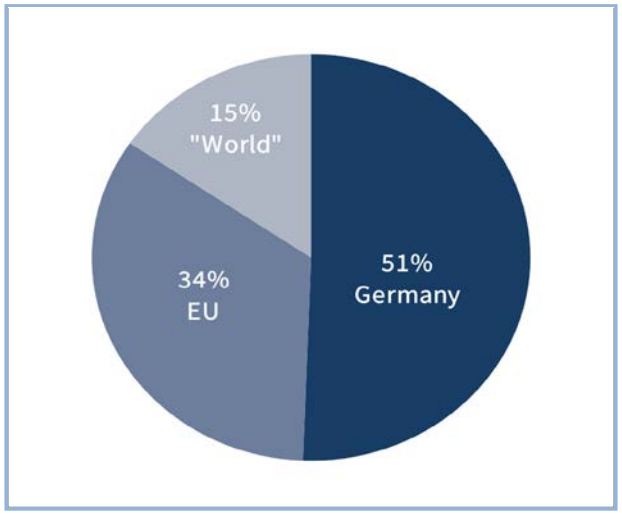




The world is visting BESSY

Origin of proposals BESSY II (2014 - today)

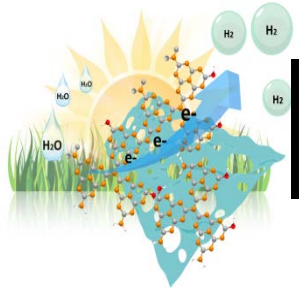


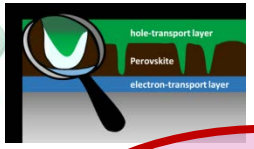


Average numbers per year (before Corona):

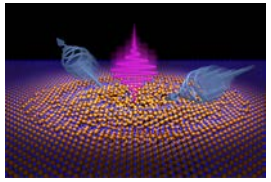
- More than 1200 proposals per year
- About 800 beamtime campagnes
- Up to 3000 user visits
- More than 11000 registered users
- 12000 overnight stays in the guesthouse
- More than 500 verified publications

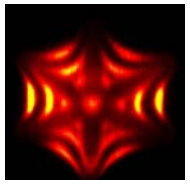
BESSY II– MULTITUDE OF USERS AND RESEARCH FIELDS



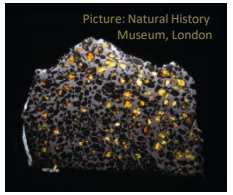


Energy & Energy Storage





Physics

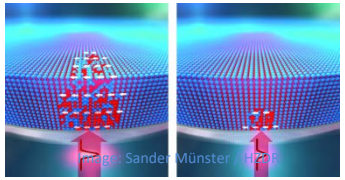


Space

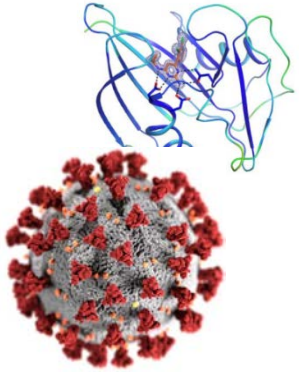
Metrology

Cultural Heritage

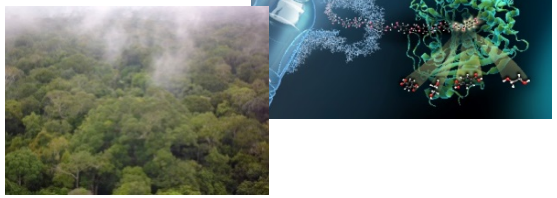
Information



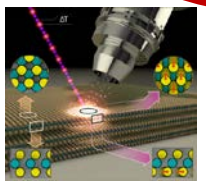
Medicine & Biology

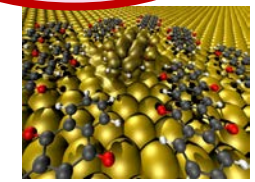


Environment

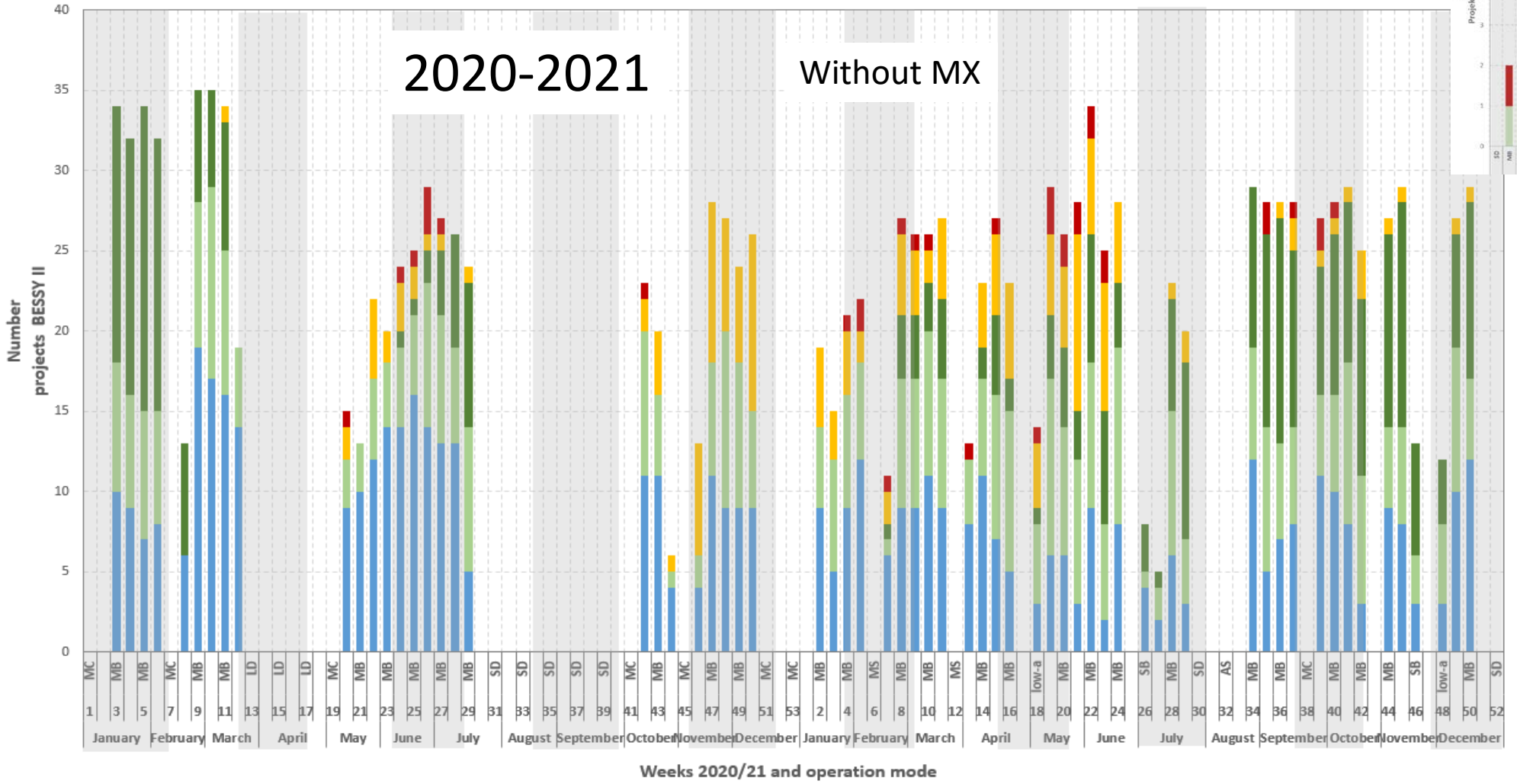


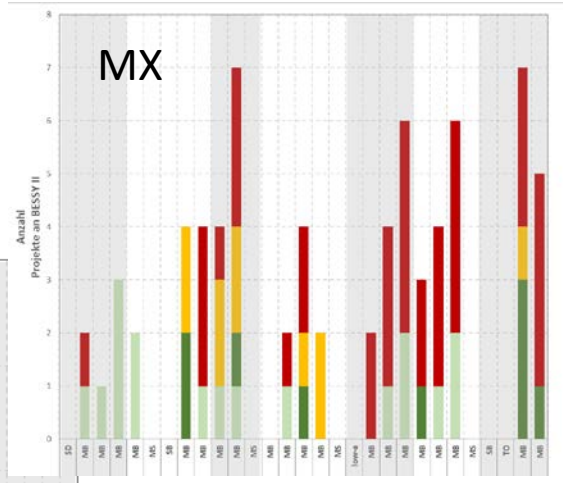
Chemistry & Catalysis

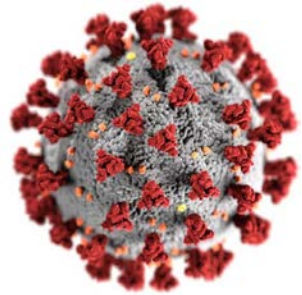




The Corona Challenge







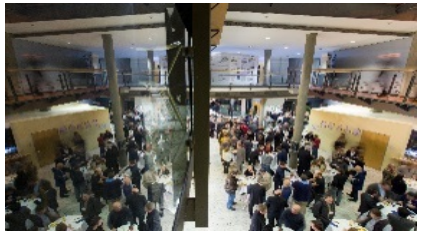
Blue: HZB, light green: users from the Berlin area, dark green: external users (except Berlin), yellow: staff assisted beamtime, red: remote beamtime

BESSY II and her sisters in the world

Users and user communities

Changes and Challenges

Beyond brilliant science



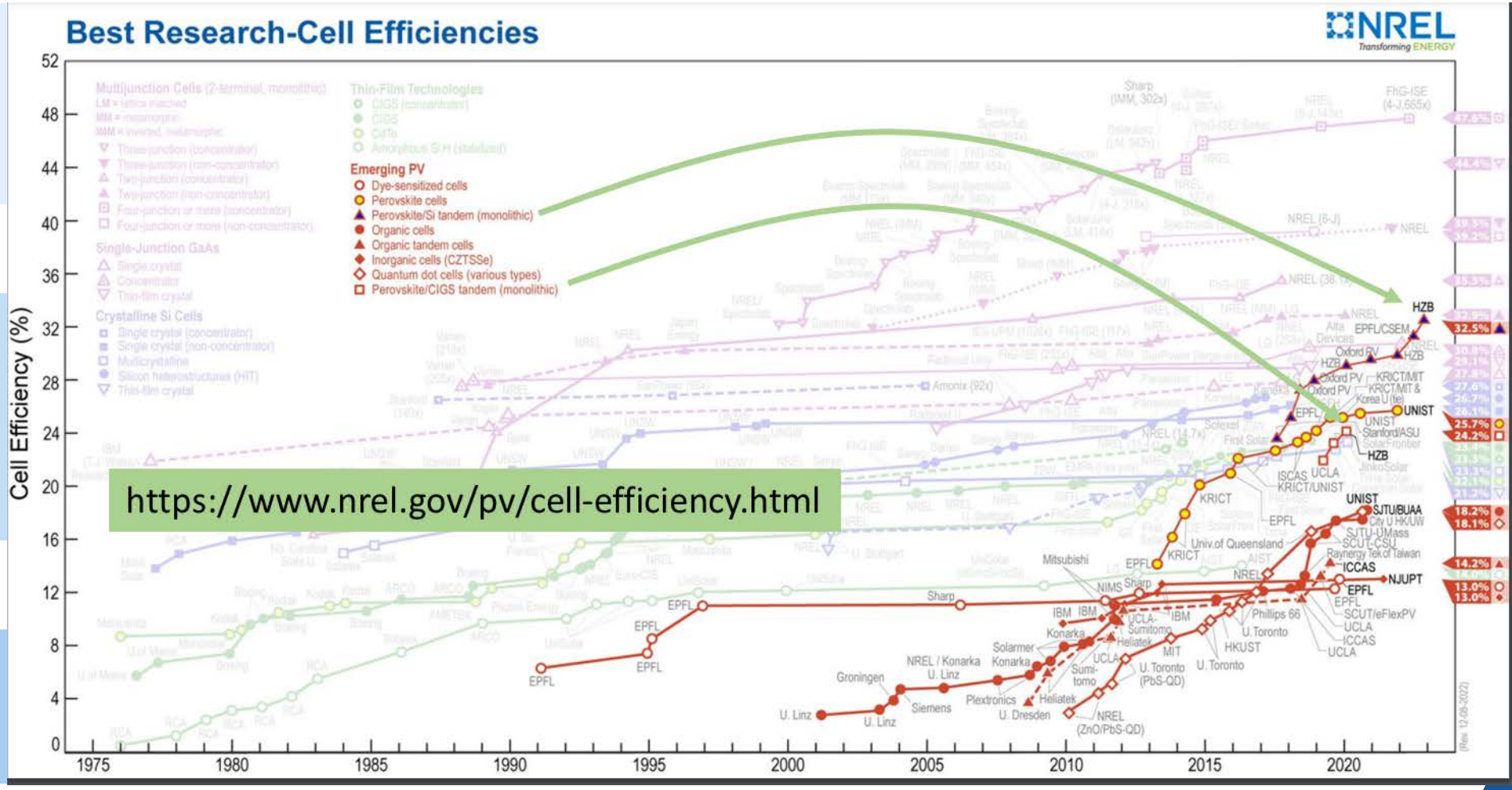
SCIENTIFIC CHALLENGES

SUSTAINABLE ENERGY - CLIMATE – ENVIRONMENT - INFORMATION TECHNOLOGY – HEALTH – MATERIALS – BASIC RESEARCH

60 Minutes:
the sun delivers the energy the whole world needs in one year[1]

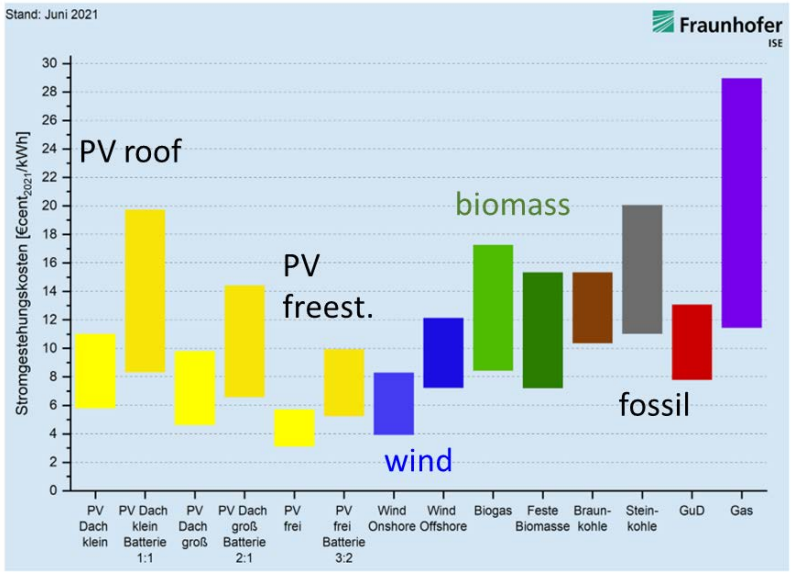
567x567 km²:
of solar panels in the Sahara (3,5% of the area) would satisfy the world‘s energy demand.

22m²
Of solar panels cover the need of an average household



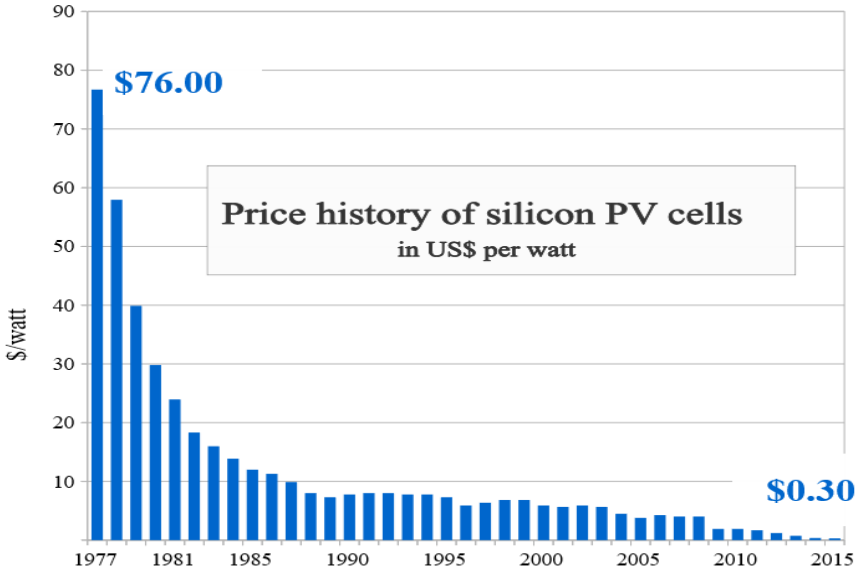
[1]BP Statistical Review of World Energy 2018, 67th edition 2018, Weltenergieverbrauch 2017: 157135,25 TWh

PHOTOVOLTAICS

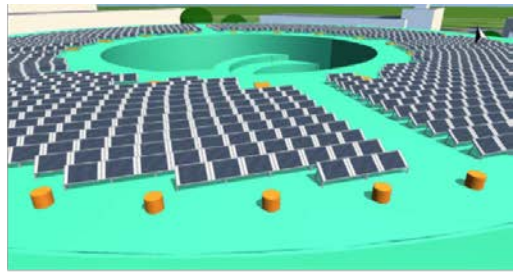


Building integrated photovoltaics Up to 50kW 360 CIGS-Solar Modules

https://www.helmholtz-berlin.de/projects/baip/



Source: Bloomberg New Energy Finance & pv.energytrend.com



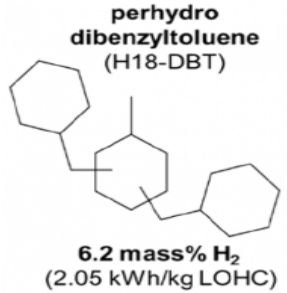
BESSY II PV roof (600 MWh p.a.) & heat recovery (1.2 MW all year) → annual energy consumption costs can be reduced by approx. 500.000 €


But if the sun does not shine?

HIGHLIGHT – ENERGY STORAGE

Towards a Hydrogen-free Hydrogen Economy – just borrow H from a molecule

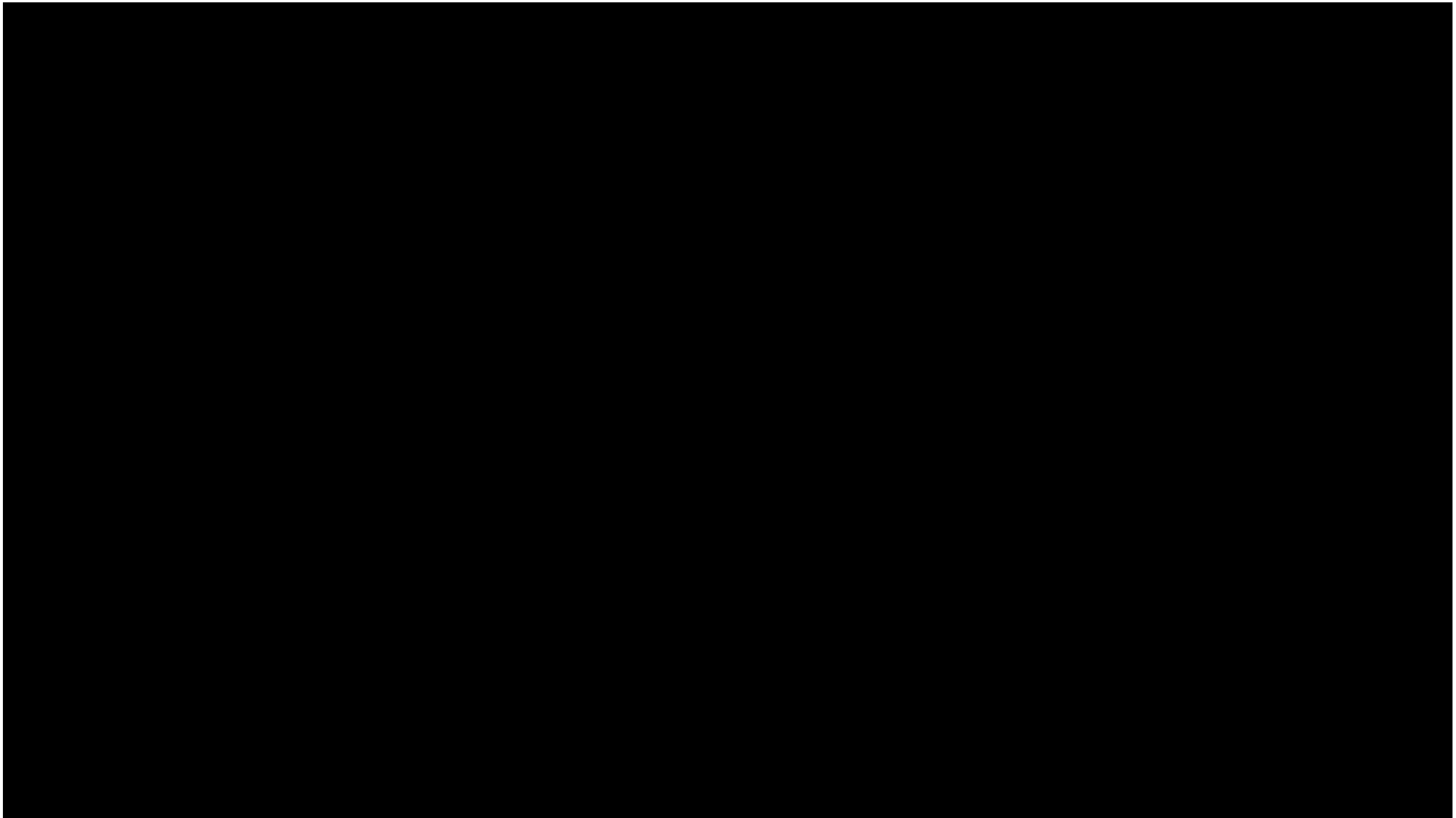
The nature of hydrogen requires dedicated infrastructures. So far this has prevented the introduction of elemental hydrogen into the energy sector to a large extent.



- liquid organic hydrogen carrier (LOHC): pairs of hydrogen-lean and hydrogen-rich organic compounds.
- A future hydrogen economy may work without handling large amounts of elemental hydrogen.
- Repeated catalytic hydrogenation and dehydrogenation cycles.
- Use of the existing infrastructure for fuels, public confidence in dealing with liquid energy carriers.

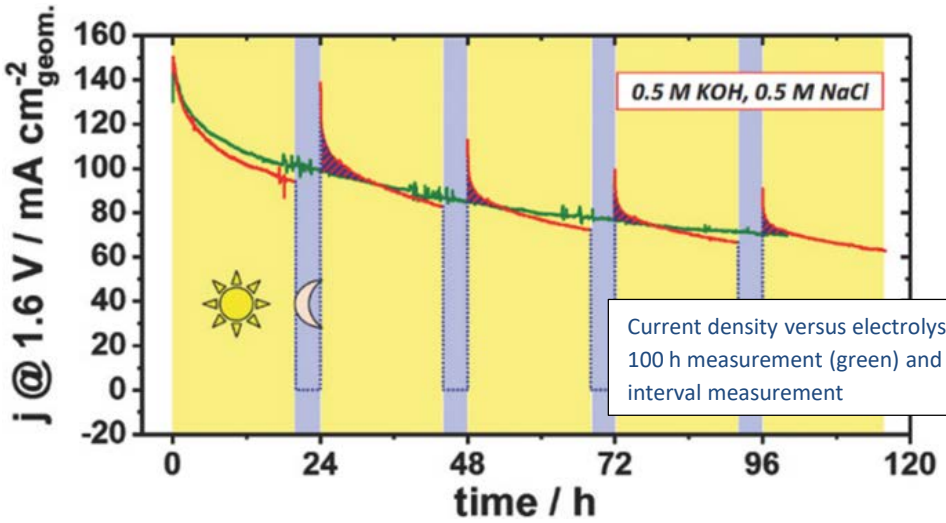
FAU Erlangen

Acc. Chem. Res., 2017, 50 (1), pp 74–85,doi:10.1021/acs.accounts.6b00474, BESSY II Instrument UE56/2 and U49



HIGHLIGHT – ENERGY

Oversalted? That's good! Electricity only during the day?
An advantage! Direct electrolytic splitting of seawater



Current density versus electrolysis time for a continuous 100 h measurement (green) and a 20 + 4 h day/night interval measurement

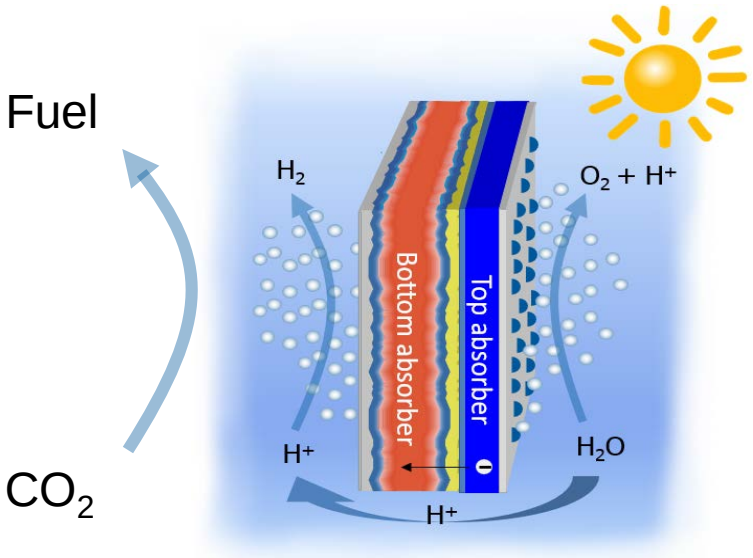
Current water electrolyzer technologies only split either highly alkaline (20–40 wt% KOH) electrolyte obtained from purified freshwater or else purified freshwater alone.
Seawater electrolysis faces fundamental chemical challenges

- First efficient working alkaline electrolyzer, splitting artificial alkaline seawater, based on nanostructured NiFe-layered double hydroxide (anode) and Pt nanoparticles (cathode).
- The natural day-night cycles could function as a refreshment protocol when using renewable energy sources like photovoltaics or wind power to operate the electrolyzer.
- Direct use of the vastly more abundant seawater supplies could solve the problematics related to scarce water provision and high fresh water demand, which are severe in many arid zones.

FU/TU Berlin

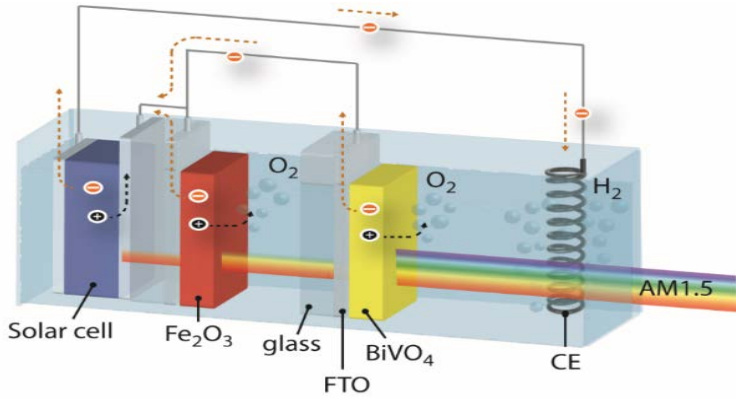
Adv. Energy Mater. 2018, 8, 1800338 DOI: 10.1002/aenm.201800338, BESSY II Instrument KMC3-XPP

DEVELOPMENT – SOLAR FUELS



From green hydrogen various pathways can lead to synthetic gas, alcohol or ammonia, being starting products for higher hydrocarbons, plastics, fertilizers via catalytic reactions

		$2H^+$ +	$2e^-$	→	H_2	
CO_2	+	$2H^+$ +	$2e^-$	→	$CO + H_2O$	
CO_2	+	$4H^+$ +	$4e^-$	→	$HCHO + H_2O$	(formic acid)
CO_2	+	$6H^+$ +	$6e^-$	→	$CH_3OH + H_2O$	(methanol)
CO_2	+	$8H^+$ +	$8e^-$	→	$CH_4 + 2H_2O$	(methane)
$2CO_2$	+	$12H^+$ +	$12e^-$	→	$C_2H_4 + 4H_2O$	(ethylene)
N_2	+	$6H^+$ +	$6e^-$	→	$2NH_3$	(ammonia)



7.7% solar-to-H_2 efficiency *en route* to the goal for practical solar hydrogen production, *Nat. Commun.* 7, 13380 (2016)

- Key challenge 1: Understanding surface chemistry during operation
- Key challenge 2: Optimizing catalysts for the different reactions
- New developments in synchrotron methods allow study of solid-liquid interfaces with XPS

BelChem FHI,HZB

J. Electron Spectrosc. Relat. Phenom. 221, 106 (2017); J. Phys. Chem. B 122, 801 (2018)

https://www.helmholtz-berlin.de/projects/catlab/index_de.html

CATlab

BATTERIES

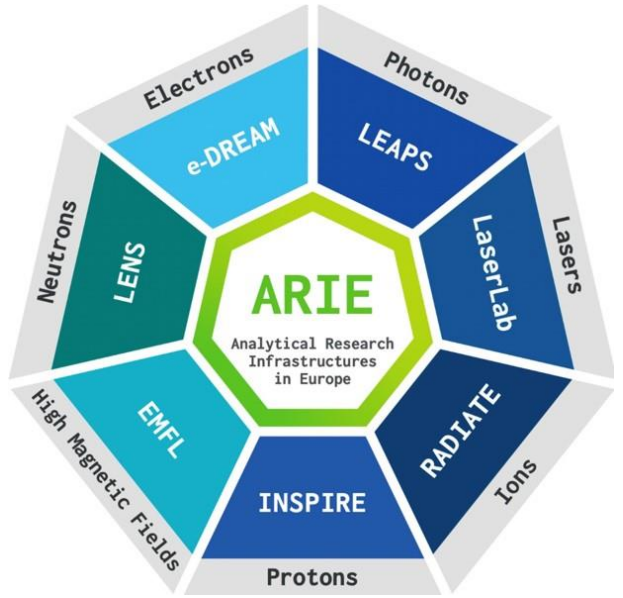
Batteries - the major technological challenge for green energy storage

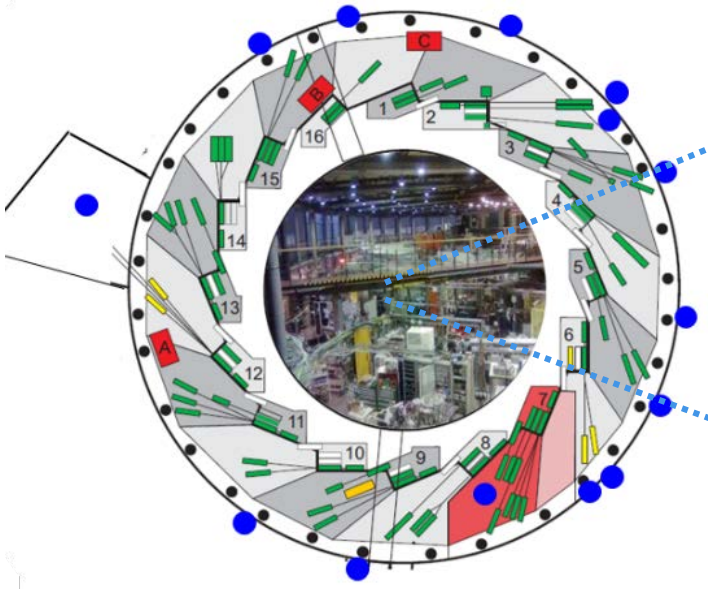
The perfect battery

- has a high capacity,
- short charging times,
- long-term stability (many charge-discharge cycles),
- is light weight and
- consists of abundantly available cheap materials.

All these properties can already be fulfilled, yet not in one but “rather 4 different batteries”.

Molecular understanding, is required for rational design of new batteries





More than 20 national and international groups working on battery research

Currently at **12 BESSY II beamlines**

Applying **10 different scientific methods**

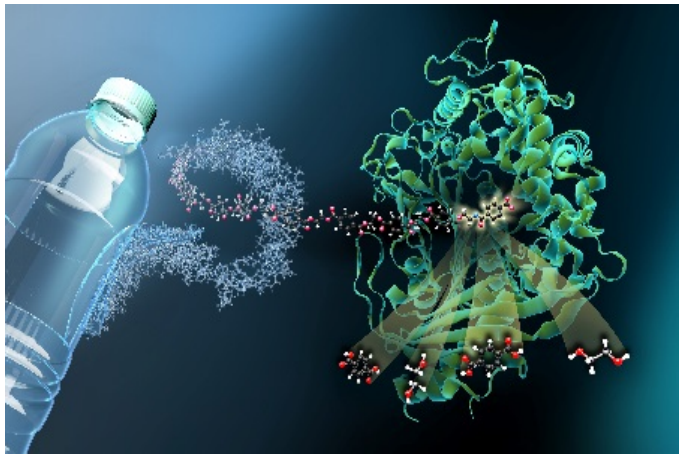
User community in this field is growing

All European synchrotrons have accepted the battery challenge (see: LEAPS paper:European Battery 2030+) More than that , ARIE (Analytical Research Infrastructures In Europe) addresses 40,000 researchers in academia and industry

Kia, Hyundai skip hybrid car developments in favour of fully electric cars, VW develops two way batteries for grid solutions

HIGHLIGHT - ENVIRONMENT

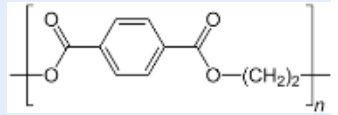
Combat plastic waste -a genuine recycling process for PET materials



MHET-molecules from PET plastic dock at the active site inside the MHETase and are broken down into their basic building blocks. © M. Künsting/HZB

Plastics are excellent materials: extremely versatile and almost eternally durable.

After only about 100 years of producing plastics, plastic particles are now found everywhere – in groundwater, in the oceans, in the air, and in the food chain.



50 million tons of PET (Polyethylenterephthalat) are newly produced every year

100 Mio

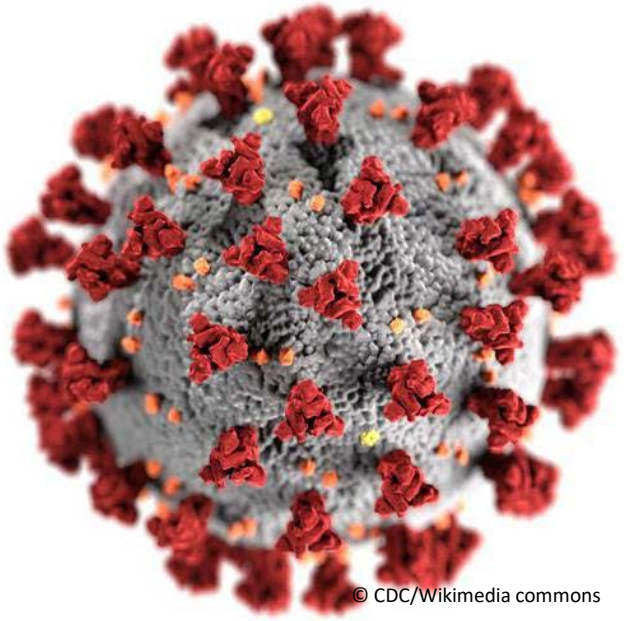
A yellow chain 4 times around the globe, just PET

- Discovery of a bacterium that grows on PET and partially feeds on it.
- Bacterium possesses two special enzymes, which are able to digest PET plastic polymers. one breaks down the plastic into smaller PET building blocks (“PET monomer”), the other splits this into the two basic precursor building blocks of PET, terephthalic acid and ethylene glycol.
- Synthesising new PET without the addition of crude oil, a closed sustainable production and recovery cycle.

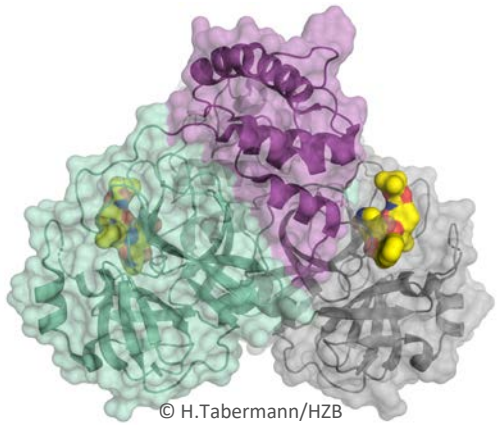
Uni Greifswald/HZB

Nature Communications (2019) DOI : 10.1038/s41467-019-09326-3, BESSY II MX-Beamline

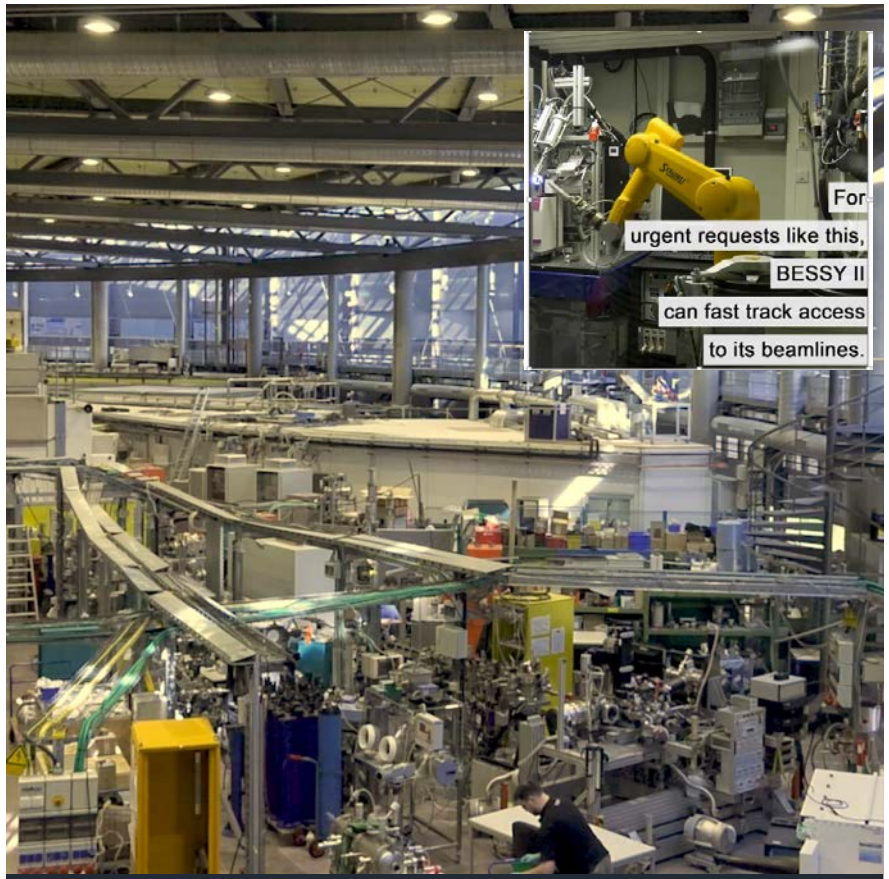
CORONA RESEARCH AT BESSY II



© CDC/Wikimedia commons



© H.Tabermann/HZB



https://www.helmholtz-berlin.de/forschung/unsere-forschung/photonenforschung/proteinkristallographie-an-bessy-ii_en.html

At BESSY II, Prof. Rolf Hilgenfeld (Uni Lübeck) was able to analyse an important protein of the SARS-CoV2 virus, the viral main protease which enables the virus to multiply.

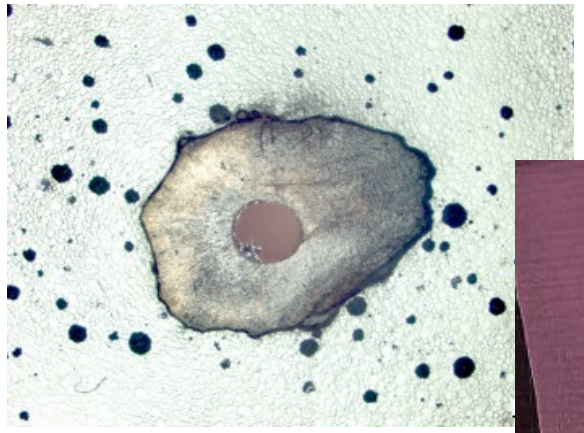
In the first year of the pandemic, synchrotron based research led to one Corona-relevant publication every 5 days!

Crystal structure of SARS-CoV-2 main protease provides a basis for design of improved α-ketoamide inhibitors
DOI: 10.1126/science.abb3405

Uni Lübeck

DENTISTRY

Root canal treatment – not as bad as you think



Optical image of a filled root.
© P. Zaslansky

A section along a treated root canal (filling in pink) reveals dentine cracks by phase contrast-enhanced µCT.© P. Zaslansky

Root canal treatment is sometimes necessary….

The procedure involves drilling an opening through the crown in order to reach the inflamed pulp and remove it.

One unfortunate possible complication is root fracture. Causes for such fractures are not fully understood, but it was suggested that stresses in the roots arising from the mechanical instrumentation may contribute to the appearance of cracks.

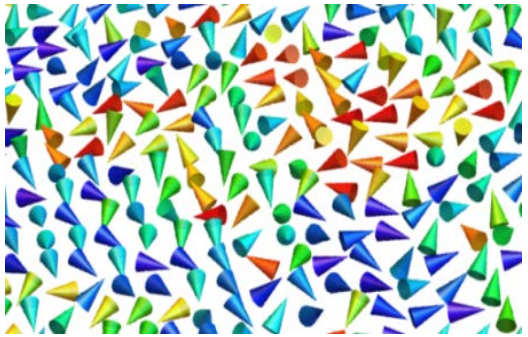
- Extracted teeth from the dental clinic at Charité were treated at a dental lab at the beamline and examined for possible cracks before, during, and after root canal treatment.
- The good news. Mechanical treatment is not contributing to micro fractures.

Charité Berlin

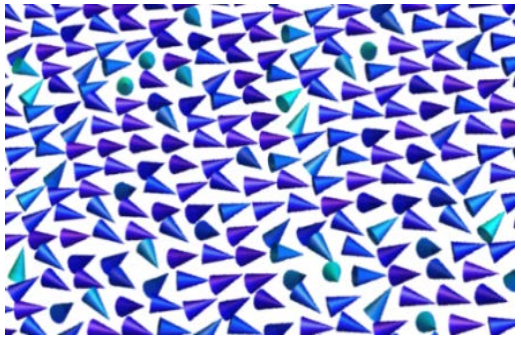
https://www.helmholtz-berlin.de/pubbin/news_datei?did=5491

HIGHLIGHT – INFORMATION TECHNOLOGY

Spintronics by "straintronics": Superferromagnetism with electric-field induced strain



Magnetization of the nanoparticles. In the absence of electric field . Random orientation of their magnetization, known as superparamagnetism.



With anelectric field, the strain induced on the BaTiO3 substrate is transferred to the nanoparticles forcing their realignment, known as superferromagnetism.

Data storage in today's magnetic media is very energy consuming.

A combination of novel materials and the coupling between their properties could reduce the energy needed to control magnetic memories → a smaller carbon footprint of the IT sector.

By the way:
did you know that each email produces 10g CO_2
The number of spam mails is about 300 Billion per day (May2020, Cisco)

- Switching magnetic domains requires normally magnetic requiring large amounts of electrical power.
- Magnetic order on a small region of the sample can be achieved by employing a small electric field instead of using magnetic fields unsing a ferroelectric and ferroelastic material $BaTiO_3$ as substrate.
- Strain is transmitted to the iron nanograins on top of it and formerly superparamagnetic regions switch to a new state: a collective long-range ferromagnetic order known as superferromagnetism.

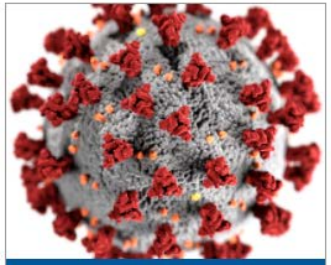
CNRS/ICMAB and Uni Barcelona/HZB

DOI: 0.1103/PhysRevMaterials.3.024403, BESSY II Instrument UE49-SPEEM

RESEARCH FIELDS, METHODS AND INFRASTRUCTURE

https://www.helmholtz-berlin.de/pubbin/newsroom

https://www.helmholtz-berlin.de/forschung/unsere-forschung/photonenforschung/corona-forschung_en.html#c495658

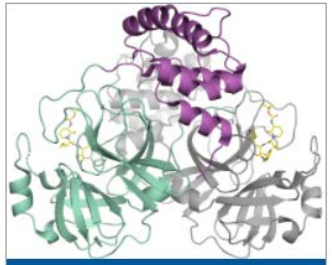


NEWS

04.05.2020 - #Corona: HZB resumes operation step by step

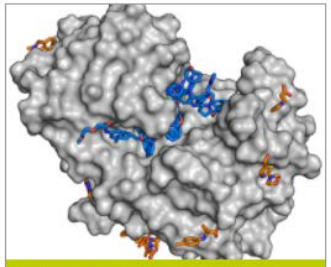
NEWS

Corona research: Consortium of Berlin research and industry seeks active...



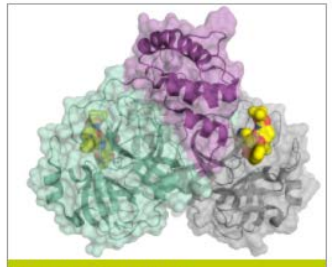
NEWS

Corona research at BESSY II: Two days of measuring operation to find the right...



SCIENCE HIGHLIGHT

New substance library to accelerate the search for active compounds



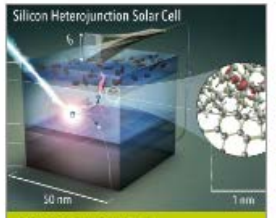
SCIENCE HIGHLIGHT

Coronavirus SARS-CoV2: BESSY II data accelerate drug development

Videos

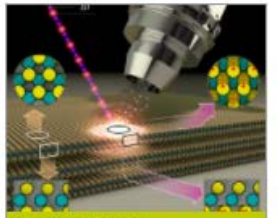
Virtual Tours

Sear results - Rubric: Science Highlight



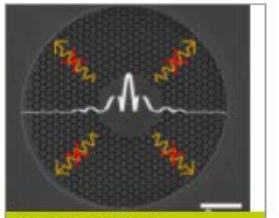
SCIENCE HIGHLIGHT

Solar cells: Losses made visible on the nanoscale



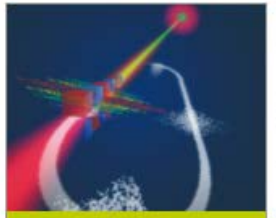
SCIENCE HIGHLIGHT

Instrument at BESSY II shows how light activates MoS2 layers to become catalysts



SCIENCE HIGHLIGHT

New skills of Graphene: Tunable lattice vibrations



SCIENCE HIGHLIGHT

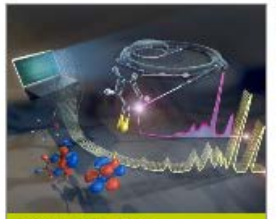
Accelerator physics: Experiment reveals new options for synchrotron light...

SCIENCE HIGHLIGHT

The perfect recipe for efficient perovskite solar cells

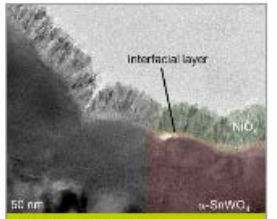
SCIENCE HIGHLIGHT

World's first video recording of a space-time crystal



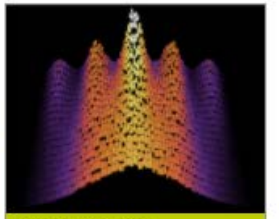
SCIENCE HIGHLIGHT

An efficient tool to link X-ray experiments and ab initio theory



SCIENCE HIGHLIGHT

Solar hydrogen: Photoanodes made of α-SnWO4 promise high efficiencies



SCIENCE HIGHLIGHT

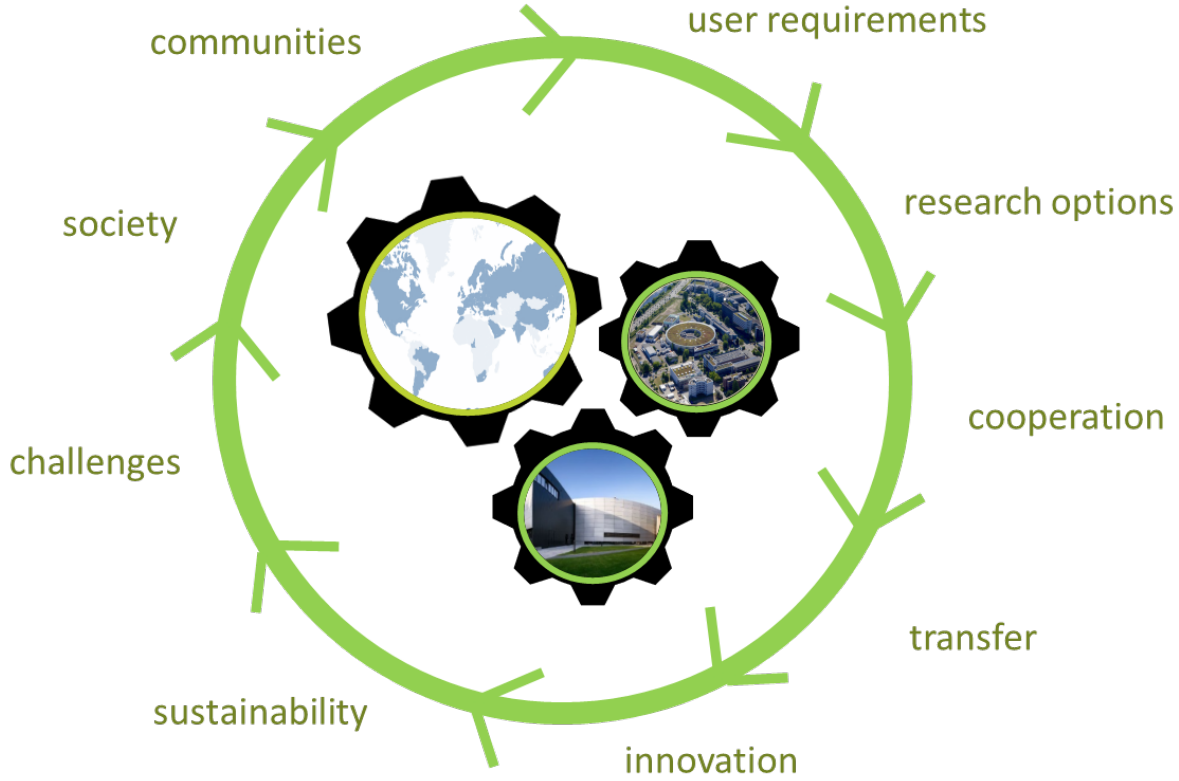
How complex oscillations in a quantum system simplify with time

BESSY II and her sisters in the world

Users and user communities

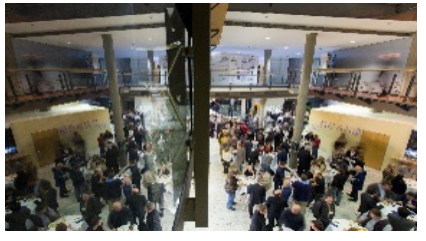
Changes and Challenges

Beyond brilliant science









Global challenges

The role of Science: discover, publish, innovate, share…

The role of Large Scale Research Infrastructures:
enable the best science
bring people together,
pave the way for peaceful cooperation

We need to bring people from all regions of the world together for the benefit of humans and society

https://www.lindau-nobel.org/a-driving-force-towards-peace-scientific-cooperation/ Picture: iStock.com/Rawpixel Ltd

CERN – Fostering cooperation between peoples recently in conflict

Examples of bridges between peoples built by CERN

- 1st intergovernmental organisation that Germany joined after WW II (on probation!)
- 1st post WW II meetings between German and Israeli physicists at CERN
- Collaboration between CERN and Russia at the height of the Cold War kept door open, establishes trust and was model for USA-Russian collaboration
- In the 1970s, when China was "closed"scientific contacts were pioneered at DESY and CERN – Nobel Laureat Sam Ting (MIT) got backing from Deng Xiaoping
- In 1985, when USSR-USA arms negotiations in Geneva were stalled, a dinner for Russian and American scientific advisors was arranged, which facilitates a subsequent breakthrough
- CERN had an open door policy for East European countries during the Cold War – this allowed them to quickly join CERN following the fall of the Berlin wall

1954 European Reconstruction
1st Session of CERN Council

1980 The East Meets the West
Visit of delegation from Beijing

Today The LHC brings together > 8000 scientists and some 100 nationalities

Transparency courtesy of R-D Heuer, former director of CERN

SESAME

Synchrotron-Light for Experimental Science and Applications in the Middle East

Conceived late 1990s – two aims:

- Enable construction of a facility for a broad range of scientific research beyond the means of individual members
- Foster cooperation between peoples

SESAME

The current (2018) Members of SESAME are Cyprus, Egypt, Iran (Islamic Republic of), Israel, Jordan, Pakistan, Palestine, and Turkey

In 2019 SESAME became the world's first large accelerator complex to be fully powered by renewable energy

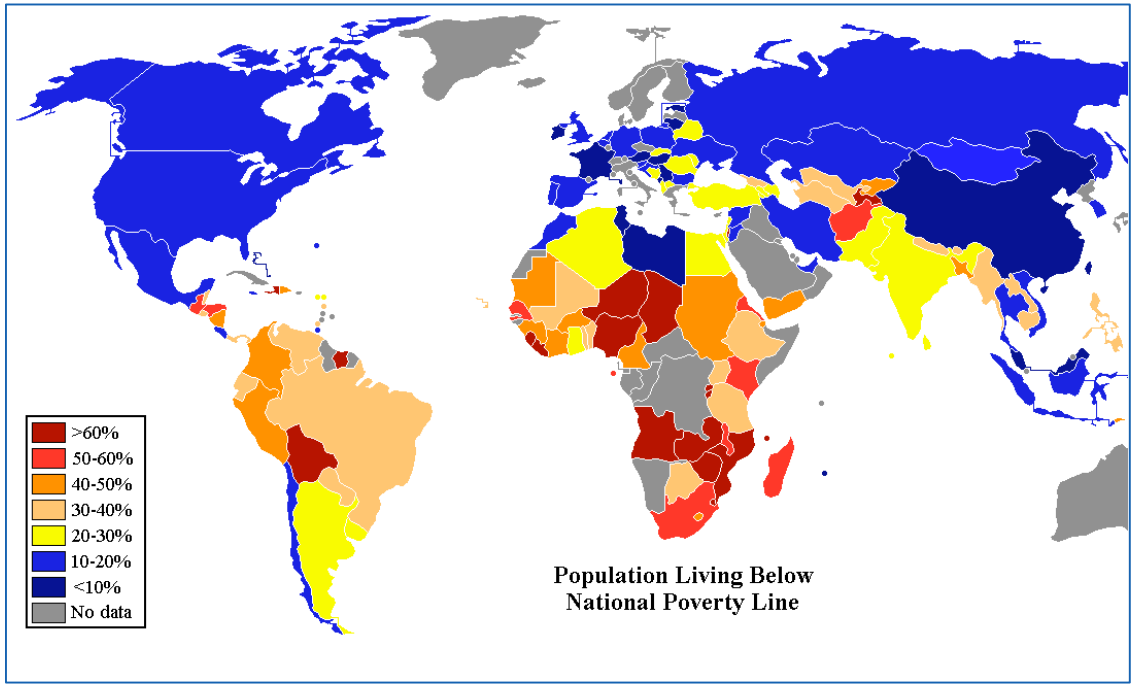
CERN and SESAME and more….

(some) lessons learned

Science bridges Cultures
Acceptance of diversity is vital
Trust between people is a mandatory ingredient
Scientists can/should/must be ambassadors for peaceful cooperation

CERN and SESAME have become examples for Science Diplomacy…

AFRICA



Currently, Africa as a whole has 169 scientist per 1 million people (cf. Europe 20 times more), a number that has to increase drastically to achieve economic development through innovation.

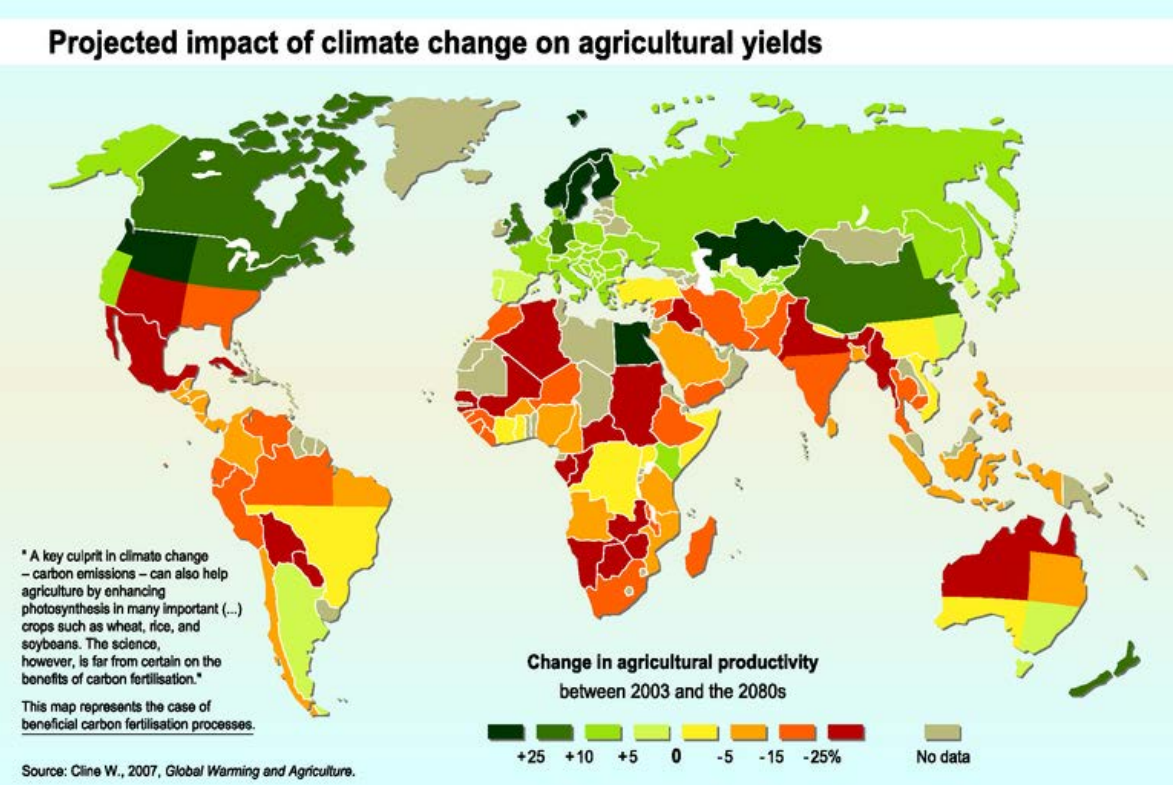
S.H. Connell et al., Towards an African Light Source, https://link.springer.com/article/10.1007/s12551-019-00578-3

AFRICA

And now, please remember the research highlights: solar energy, water splitting from sea water, transport of hydrogen in existing infrastructures, using hydrogen for solar fuels (from alcohols to synthetic aviation fuel)

But also:

every Euro spent in R&D creats 11 Euros for society.
Africa will soon become the home to the best part of the world's youth, these young people will need be part of the economy and developments in their countries.



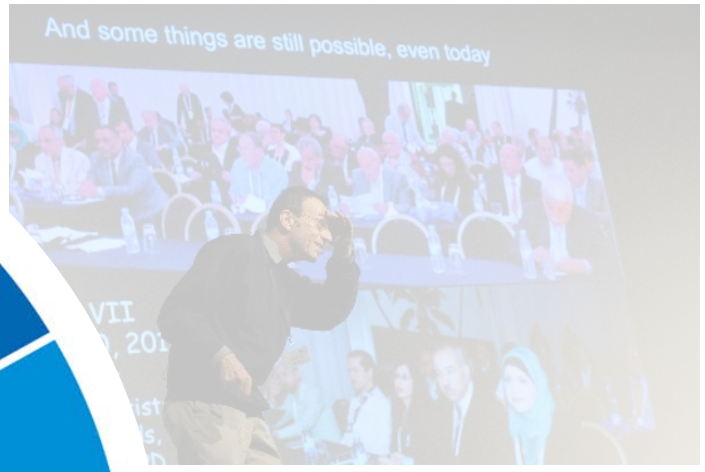
In the past the formerly so called third world was basically excluded from knowledge circulation; most of the exchange - for example at conferences - took place in the northern hemisphere.
This is changing, but more can be done to speed up a broader inclusivity.

To solve global problems, intensified transnational cooperation, distribution of knowledge, and most importantly intellectual exchange are major ingredients.

IDEA - inclusion, diversity, equity, and anti-discrimination

(some) lessons learned

Science brid
Acceptance o
Trust between peopl
Scientists can/should/must be



CERN and SESAME have b
Science Diplomacy…

LEAPS IDEA - inclusion, diversity, equity, and anti-discrimination

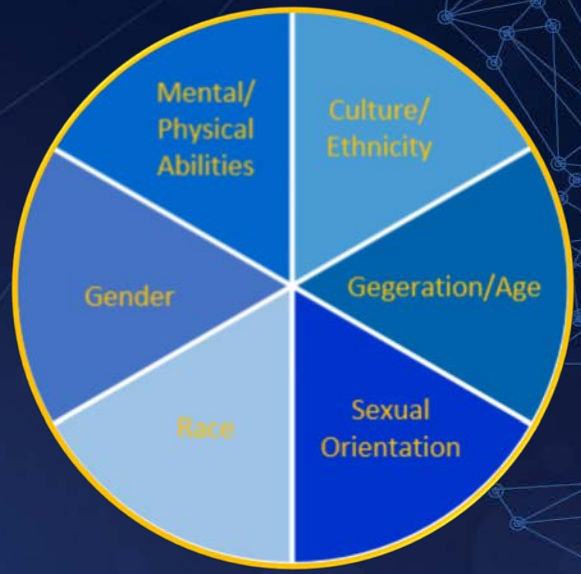
LEAPS Statement on Inclusion, Diversity, Equity, and Anti-discrimination (IDEA)

"(…) As international large-scale research infrastructures where interdisciplinary scientific topics are explored, **LEAPS facilities are inherently diverse and dynamic**. (…)

As a European consortium focusing on scientific excellence, LEAPS is committed to **strengthening diversity** and is acutely aware of owing its success to the talents, ideas, (…) and collaboration of its scientists. The ingredients to this success are respect and fairness, appreciation and openness. **Ensuring equity** and achieving an **inclusive environment**, **free from discrimination** at all levels, is LEAPS's responsibility.

The prerequisite to scientific and societal prosperity is the creation of an **atmosphere of acceptance and trust**, embracing all differences stemming from personal ways of life or personal living situations, ethnic origin, gender, sexual orientation, ideologies, biographies, religion, beliefs, disability, age, appearance, and many other aspects. In an increasingly globalised and interdependent world, cohesion matters, diversity helps, and impartiality is indispensable. (…)"

Primary Dimensions of Diversity



A lot can be done!

Diversity audit
Diversity self-report
Diversity award
Code of conduct
Persons of trust
Ombudspersons
Complaints officer

Diversity roundtable
Welcome culture
Science and society initiatives
Social hours

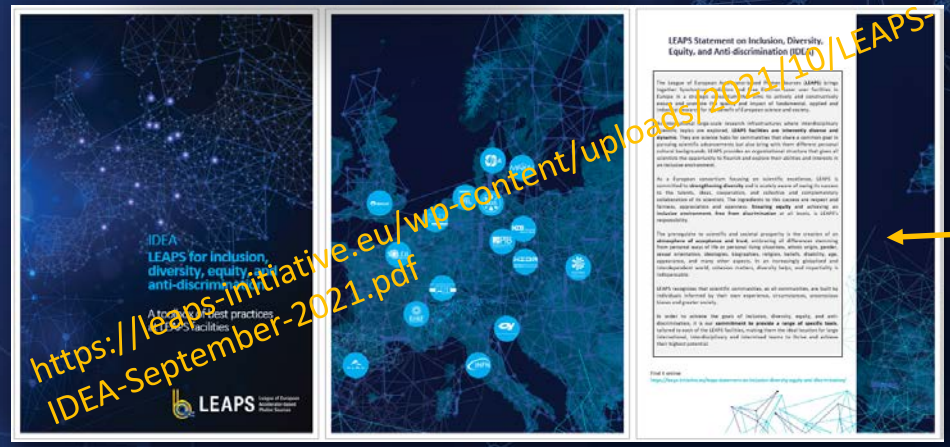
Seminars on unconscious bias
Training on prevention of sexual harassment

Best practice IDEA examples from LEAPS facilities

Dual career service
Social counseling
Multi-lingual communication
Website accessibility
Mentoring programmes
Gender equality in academic career development

Outreach events
Science diplomacy activities
Promotion of new user communities
Country of honour
Twinning programme

LEAPS IDEA document on best practice examples and toolbox



https://leaps-initiative.eu/wp-content/uploads/2021/10/LEAPS-IDEA-September-2021.pdf

Please find more best practice exmples and a toolbox for IDEA actions in this document.

LEAPS League of European Accelerator-based Photon Sources

Curiosity driven research

Daniel Zajfmann:

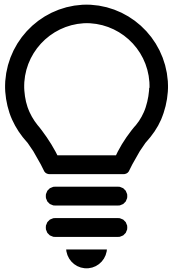
(…) If we would have been sitting here 200 and some years ago ... Well, of course there would be no projectors, no microphone, but also no light. And in any room that we would have been sitting, there would have been a lot of candles. About 200 years ago, actually mostly in the UK but also in Germany, there was a lot of R&D for candles. People were investing a lot of money to get better candles, producing more light, different colors, different perfume. (…)

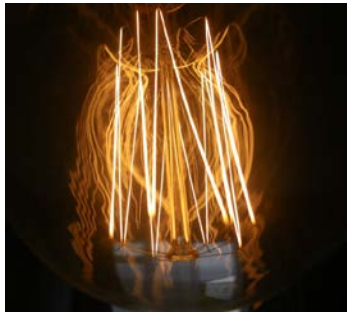
Then came this gentleman named Michael Faraday and he invented electricity. Now I want to remind you of something. It doesn't matter how much money you're going to invest in developing new candles - you will never get electricity.

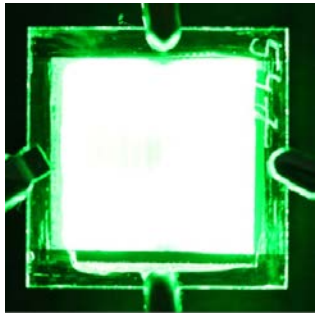
The solution to your problem is not always where the problem is. (…)

https://www.youtube.com/watch?v=Os6ilKTK5KM&t=6m22s

Therefore, it is even more important to include the whole world into the exchange of knowledge and ideas



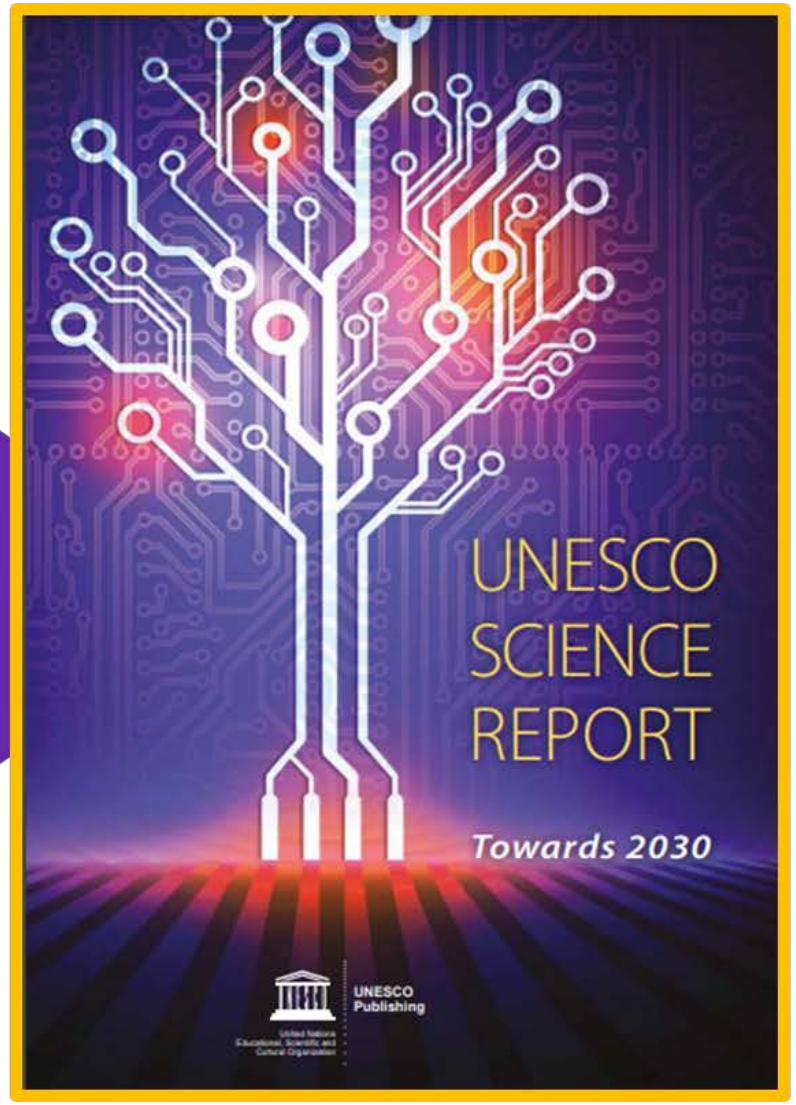




Thank you for your kind attention

https://www.lindau-nobel.org/a-driving-force-towards-peace-scientific-cooperation/ Picture: iStock.com/Rawpixel Ltd

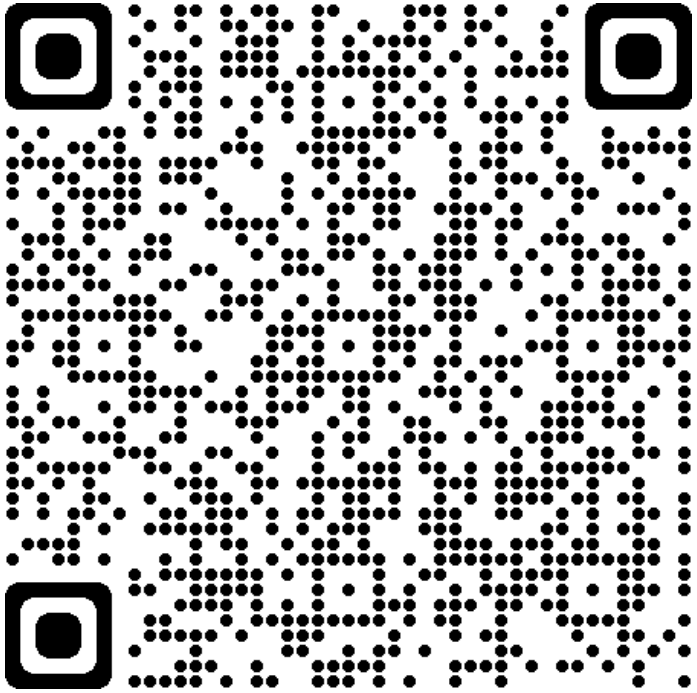
https://unesdoc.unesco.org/ark:/48223/pf0000235406



Contents

https://www.helmholtz-berlin.de/zentrum/aktuell/mediathek/index_en.html

Videos



Virtual Tours