SUSTAINABLE DESY.

Approach to sustainability at DESY

Focus PETRA IV.

A sustainable accelerator and high research performance? How can we manage it?

Concepts and first steps taken

Andrea Klumpp
9th Low Emittance Rings Workshop 2014

HELMHOLTZ

DESY.

DESY

- Technical monitoring
- Civil construction
- Waste heat usage

PETRA IV

- Permanent magnets
- Tunnel
- Robotics and telepresence
- Automated beamlines
- Remote access
- Data management
- Research

What is sustainability at DESY

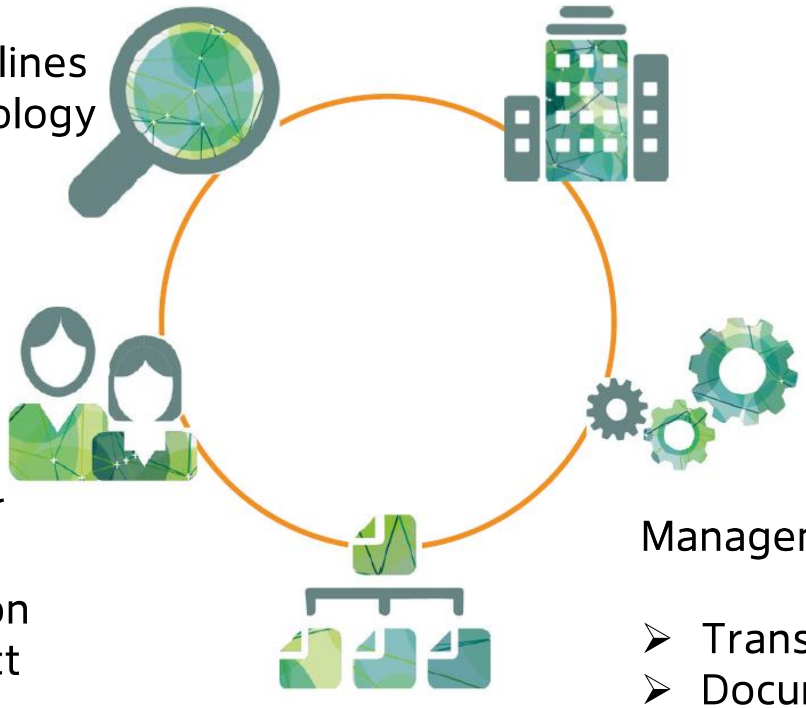
Broad approach with focus on energy efficiency

Science

- Science case supports sustainability goals
- High number of beamlines
- Innovation and technology transfer

Infrastructure

- Reuse of infrastructure
- Energy saving technologies
- New building concepts and materials



Supporting processes

- Key infrastructure of Science City Bahrenfeld
- Cooperation in campus security, safety, enviromental protection and mobility

Personnel

- Sustainable career development
- Keep knowledge on campus and attract best talents

Management

- Transparent to employees and stakeholders
- Documentation of processes and decions
- Boost socio-econimic impact (education, employment…)

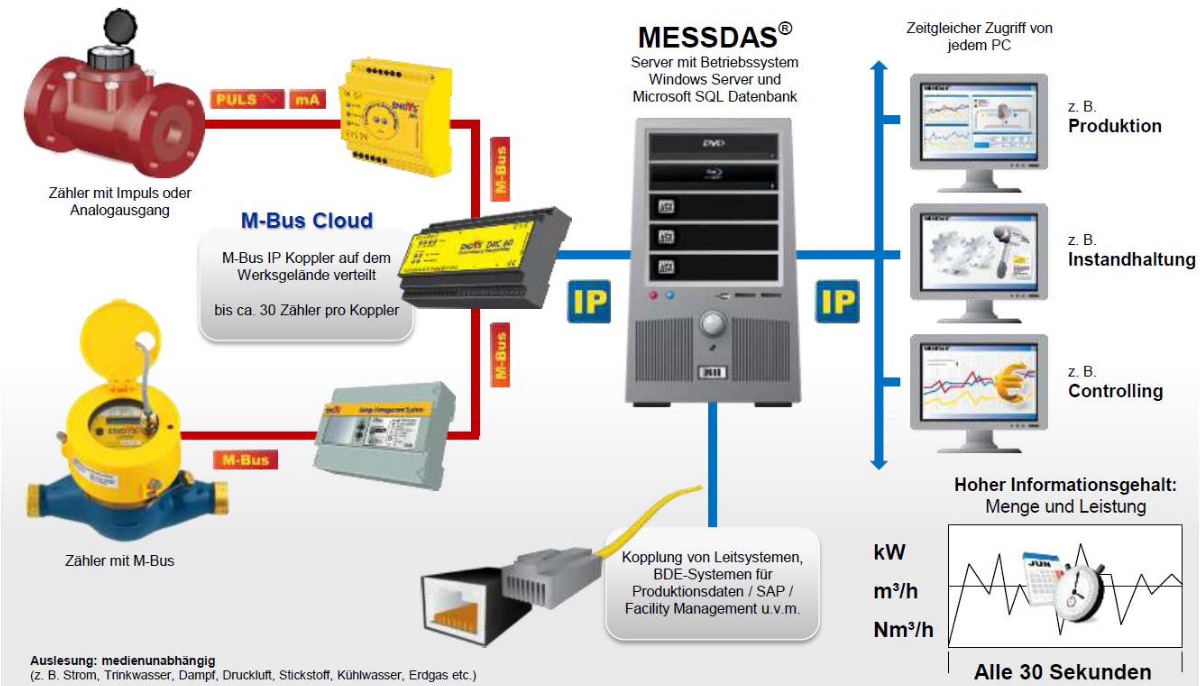
SUSTAIN ABLE DESY.

Energy approach

Energy monitoring system

- Detailed, unified meter marking, centralized data collection and analysis, meters directly connected to database
- For Electricity, Water, Heat, Cooling

→ Enables for user-based/source-related accounting, identification of efficiency potentials and therefore more awareness



DESY

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PETRA IV

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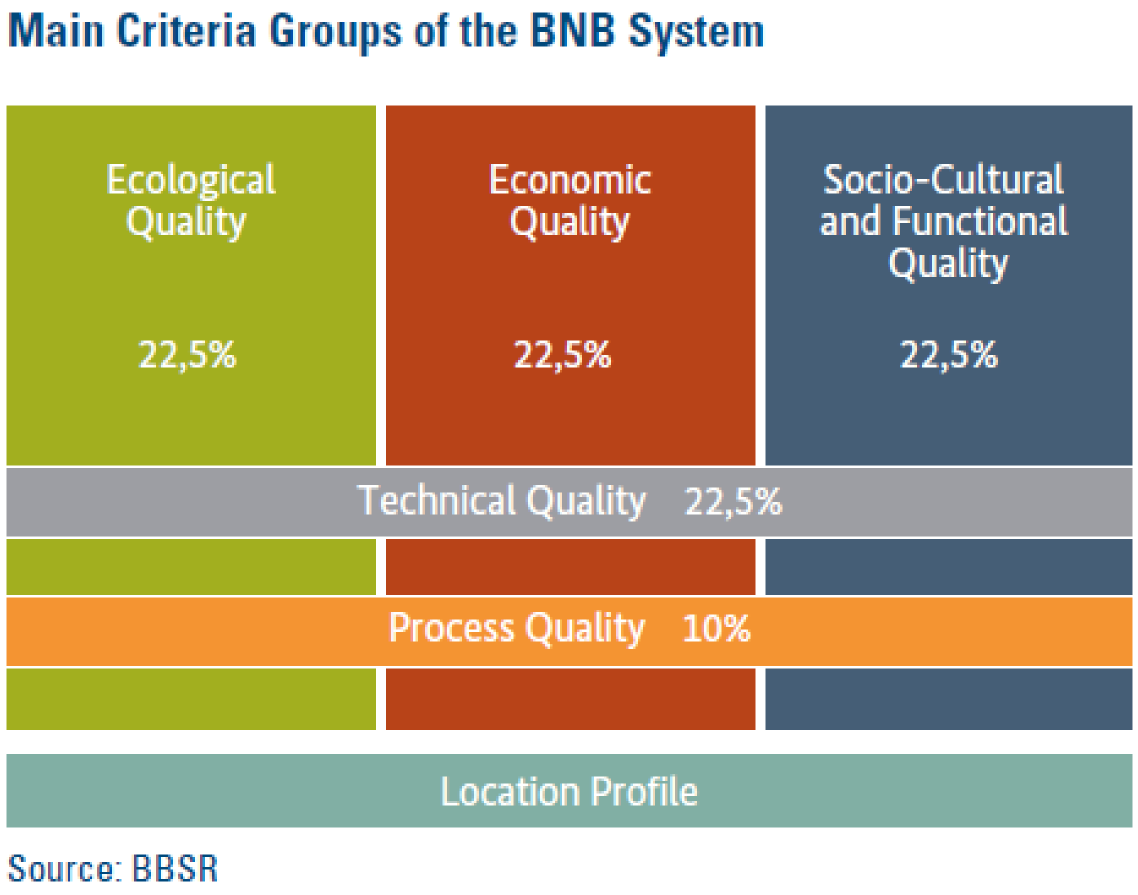
Civil construction

LCA for buildings



National certification system for sustainable building (BNB):

- Consideration of the whole life cycle of the building (LCA)
- Ecological, economic, socio-cultural and technical qualities are rated equally
- End of life and recycling are included
- BNB silver for all new buildings at DESY

SUSTAIN ABLE DESY.

DESY

- Technical monitoring
- Civil construction
- **Waste heat usage**

PETRA IV

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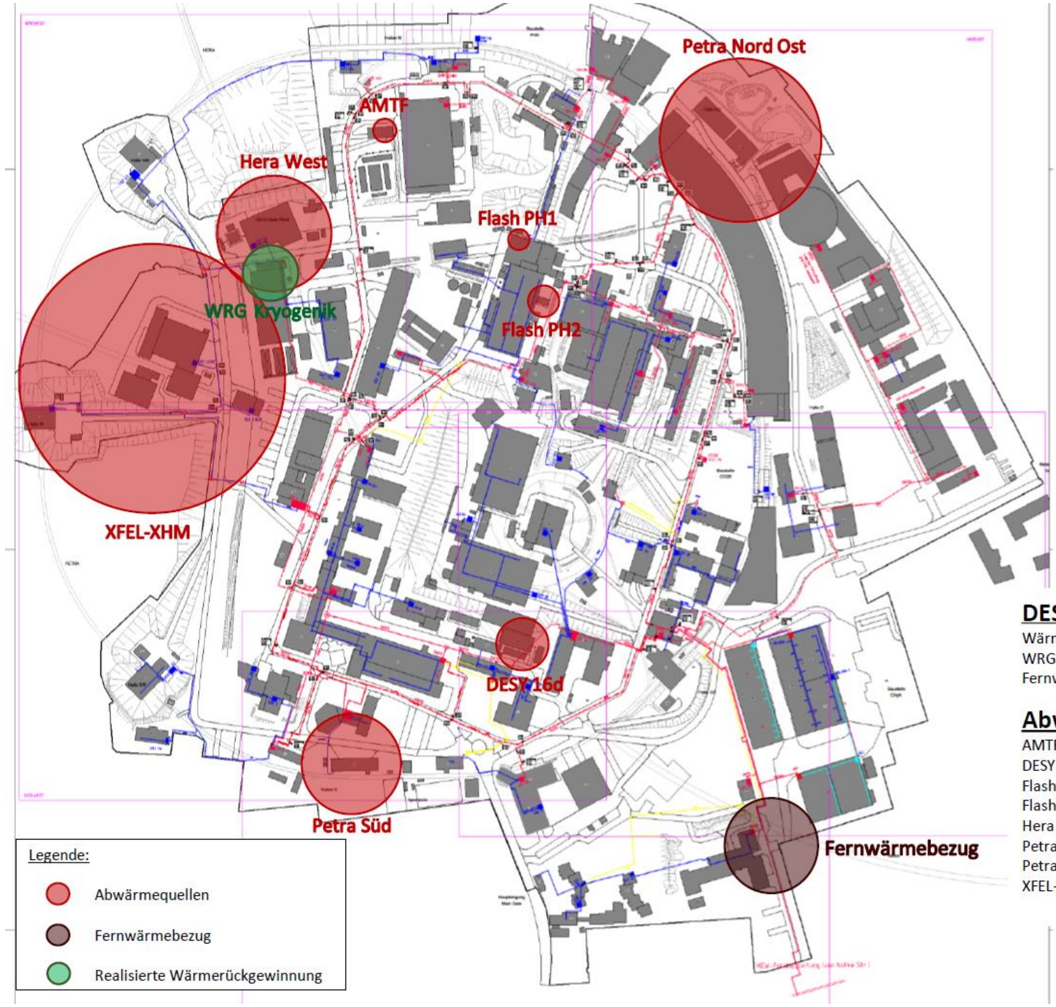
Waste heat usage

Potential at DESY Campus in Hamburg

- Currently heating is DESYs biggest CO_2 emission source
- Project with University of applied science in Hamburg (HAW) to identify potential
- Result: 129 GWh/y of waste heat available at a temperature level of 30°C - 40°C
- Possible CO_2 savings at DESY campus of about 4.000 tons/y
- Surplus can be used in neighborhood; if we get the 129GWh in use saving will be up to 40.000 tons CO_2/y



DESY Hamburg[1]:

Wärmebedarf:	23,13 GWh
WRG Kryogenik:	9,40 GWh
Fernwärmebezug:	15,73 GWh

Abwärmequellen[2]:

AMTF:	3,86 GWh	(22°C)
DESY 16d:	8,74 GWh	(30°C)
Flash PH1:	3,77 GWh	(30°C)
Flash PH2:	5,44 GWh	(30°C)
Hera West:	19,6 GWh	(29°C)
Petra Nord Ost:	26,8 GWh	(30-38°C)
Petra Süd:	16,3 GWh	(35°C)
XFEL-XHM:	44,9 GWh	(34-38°C)

1: Daten aus dem Jahr 2019 (Zertifizierung TU Dresden).
2: Daten aus dem Zeitraum ab dem 01.04.2019 bis zum 01.04.2020.

PETRA IV.
NEW DIMENSIONS

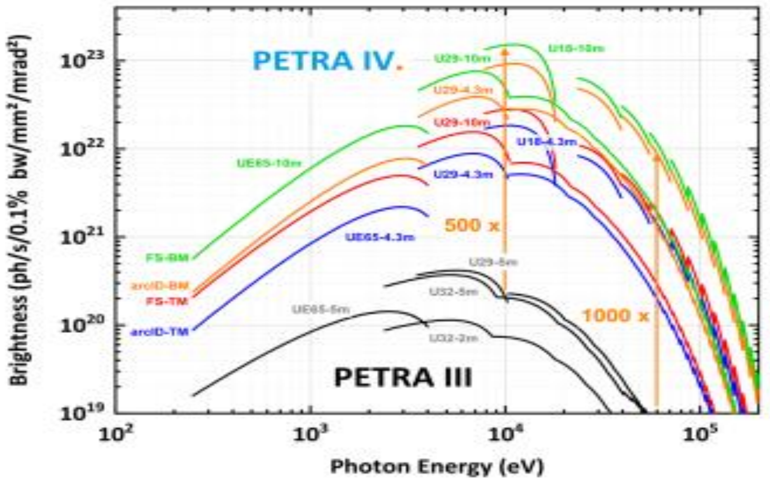
PETRA IV and Sustainability

HELMHOLTZ

DESY.

Upgrade PETRA III : PETRA IV.

What is the benefit of the upgrade?

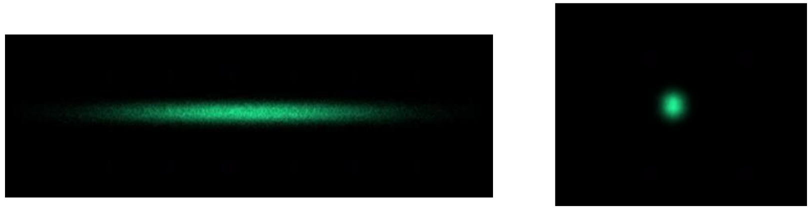


Spectral brightness of PETRA IV (H6BA lattice) compared to PETRA III [1]

Brilliance increase by
➔500 x (hard X-rays)
➔1000 x (high-energy X-rays)

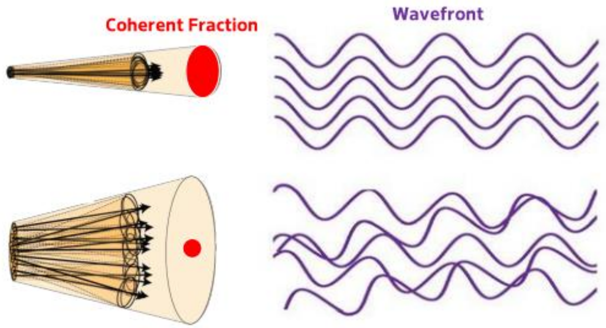
PETRA IV. brilliance at 100 keV higher than for 10 keV at PETRA III today!!

Photon source size –ideal imaging capabilities



Comparison of the beam emittance for PETRA III (left) and PETRA IV (right)

	PETRA III	PETRA IV
Horizontal	1300 pm rad	20 pm rad
Vertical	10 pm rad	5 pm rad



Coherence of the emitted light for PETRA III (bottom) and PETRA IV. (upper figure)

[1] C.G. Schroer et all **Eur. Phys. J. Plus 137, 1312 (2022)**

DESY sustainability approach for PETRA IV.

PETRA IV. NEW DIMENSIONS

- BNB silver for all new buildings at **PETRA IV.**
- New experimental hall with equivalent criteria
- Low temperature network for heating including new buildings with low temperature heating
- Technical monitoring (energy, heat and cooling)
- Energy efficiency
- Life cycle assessment
- Documentation and processes

SUSTAINABLE DESY.

Sustainable construction

Life cycle assessment (LCA)

Consider entire life meaning:

from the cradle to the cradle/grave

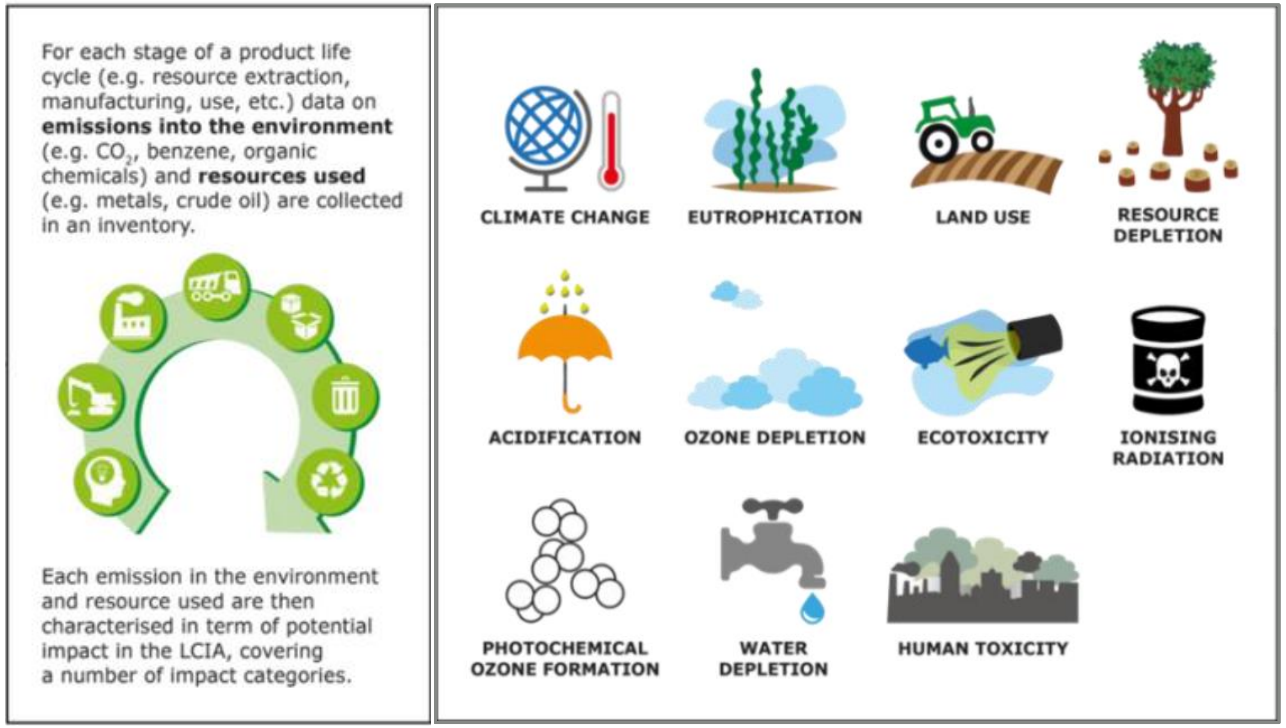
LCA contains:

- Life Cycle Inventory (LCI)
- Life Cycle Impact Assessment (LCIA)
- Life Cycle Interpretation phase

Cost analysis

- Lower operation cost justify higher investment cost, not to forget costs for decommissioning
- To lose high level materials is not only an ecological but also an economical problem

Life Cycle Inventory (LCI) | Life Cycle Impact Assessment (LCIA)



d

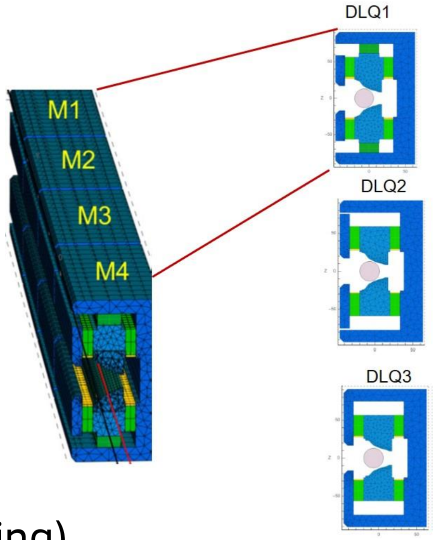
Start with LCA for power supplies
First calculations for permanent magnets are done.

Bending magnets at PETRA IV.

PETRA IV. NEW DIMENSIONS

- H6BA lattice: DLQs combine the function of a dipole and quadrupole magnets to save space
- Soft iron poles and yoke; SmCo magnets
- Thermal shims for temperature compensation
- Energy savings: **nearly 2.87 GWh/year**
  (calculated with 6500 h operation time per year; without cooling and heating)

  for all electromagnets in PETRA IV nearly 6.4 GWh per annum (6500 h operation time)

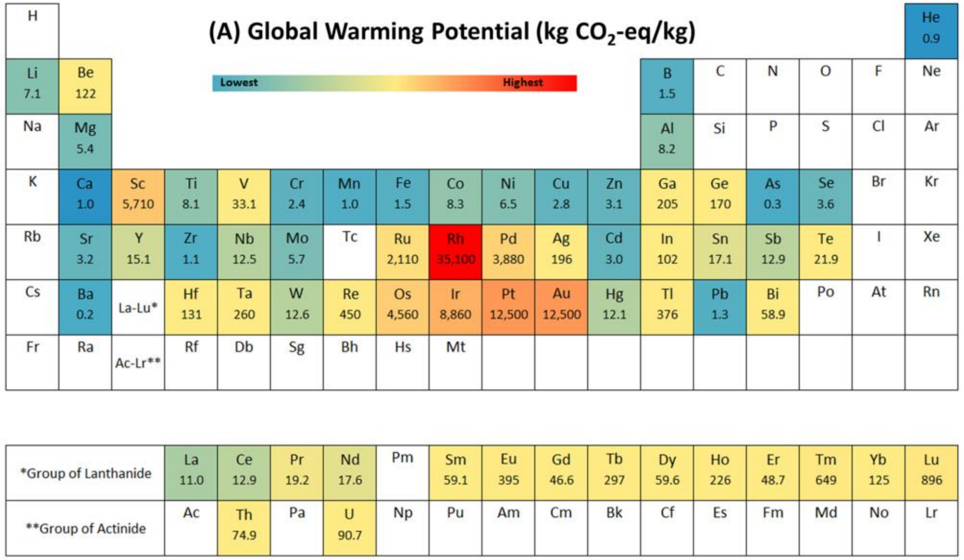


SUSTAINABLE DESY.

GHG footprint for bending magnets

PETRA IV. NEW DIMENSIONS

- First calculations for material and energy: NO! production, transport and cooling in operation included
- Literature research for Global warming potential (GWP) for materials
- Depending from included processes (eg. mining, sintering …) and mining/production region but also from data base, program for calculation values for one material differ a lot
- Here only cradle to gate calculations (for SmCo only the raw material Sm and Co)



Life Cycle Assessment of Metals: A Scientific Synthesis
Philip Nuss, Matthew J. Eckelman
www.plosone.org 1 July 2014 | Volume 9 | Issue 7 | e101298

SUSTAIN ABLE DESY.

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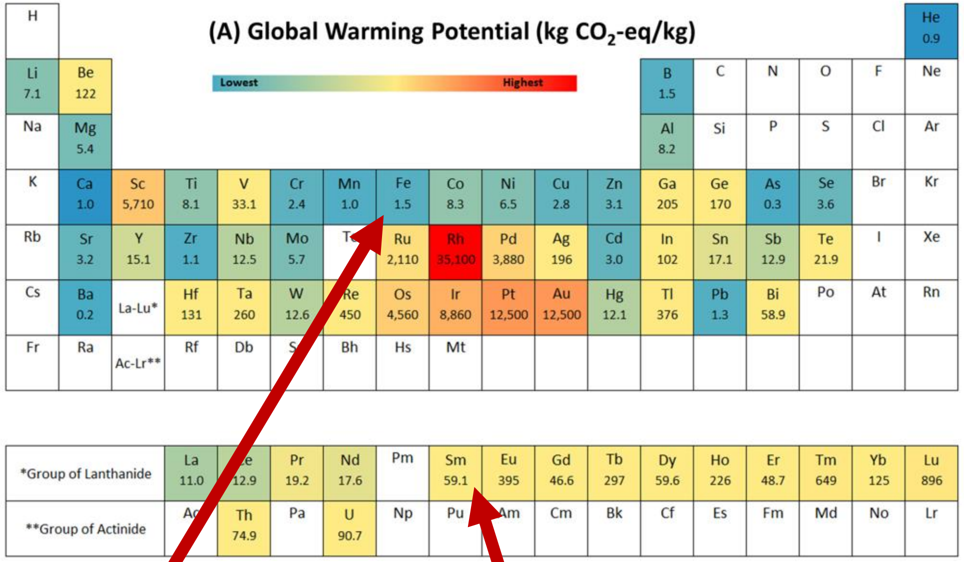

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Sm 59.1 kg CO_2 eq/kg

Fe 1.5 kg CO_2 eq/kg

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DESY

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First calculations - for bending magnets

PETRA IV. NEW DIMENSIONS

	DLQ1		DLQ2		DLQ3	
	Emag	Pmag	Emag	Pmag	Emag	Pmag
operation [kW]	1,27		0,67		1,11	
Fe [kg]	189,6	114,33	170,6	114,33	287,6	171,40
Cu [kg]	34		31		50	
Al [kg]		20		20		30
Sm_2Co_{17} [kg]		16,47		16,47		24,70
FeNi [kg]		1,2		1,2		1,8
Total weight [kg]	223,6	152,0	201,6	152,0	337,6	227,9

Material and energy consumption for DLQs

SUSTAINABLE DESY.

First calculations – for bending magnets

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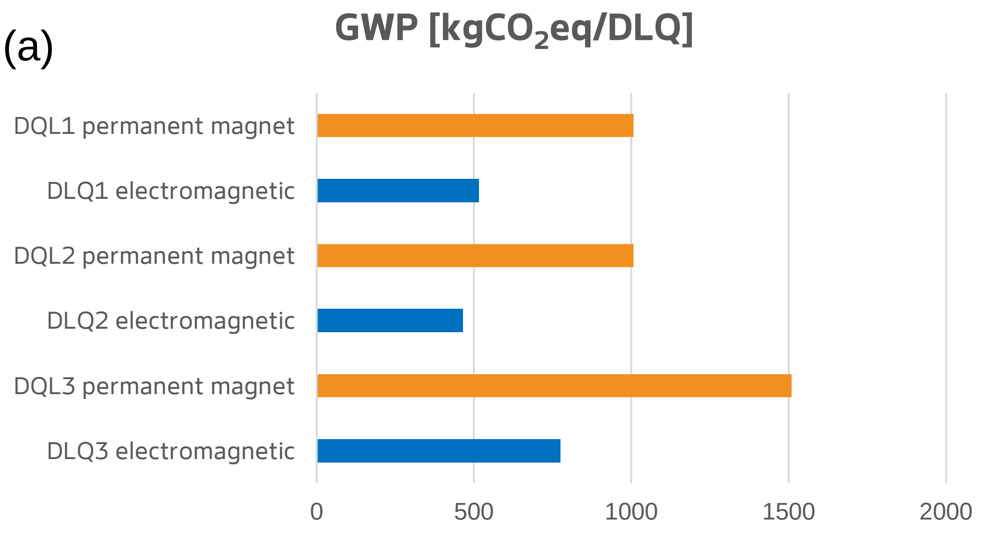
Material and energy consumption for DLQs

(a)



GWP for (a) material (electromagnets- blue and permanent magnets – orange)

SUSTAINABLE DESY.

First calculations – for bending magnets

PETRA IV. NEW DIMENSIONS

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Material and energy consumption for DLQs

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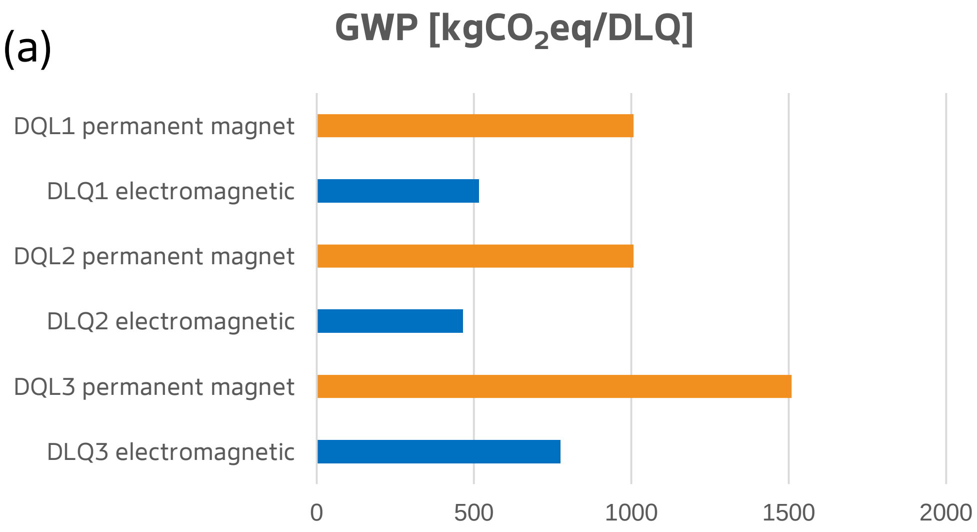
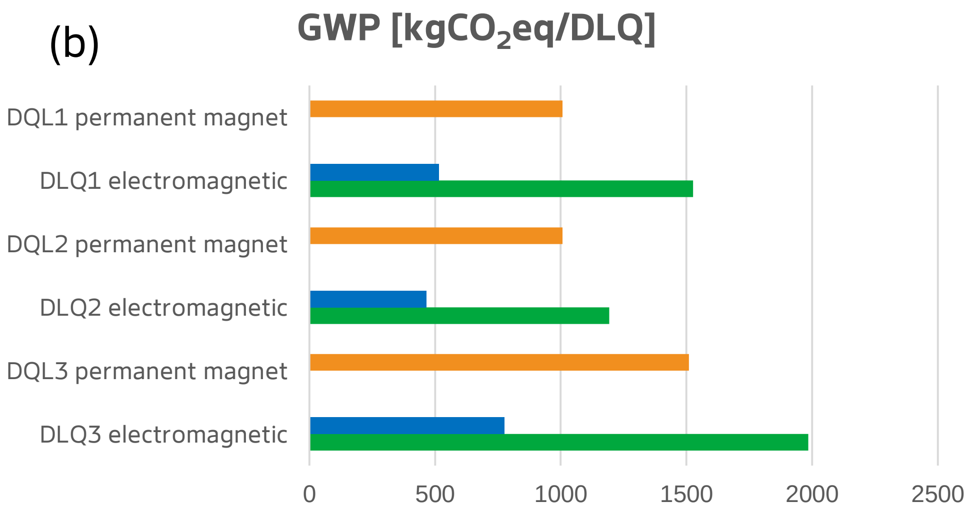


(b)



GWP for (a) material (electromagnets- blue and permanent magnets – orange)
and (b) including estimated energy consumption (material + renewable electricity for 2 years – green)

Energy GWP from UBA for renewable electricity

DESY

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Problems and challenges of permanent magnets

PETRA IV. NEW DIMENSIONS

Beginning of life cycle: Mining and Processing

- Rare earths are mined and processed under destructive social and environmental conditions
- No alternative sources or certified mining and processing available

In operation

- Temperature fluctuations and radiation damages reduce the life span
- Magnetic field is not adjustable, so changes in trajectories can not be compensated
- Magnetic field can not be switched off (Safety aspects like maintenance)

End of life cycle: Recycling

- So far no industrial recycling chain

a) **Private, illegal minning in China**; http://www.chinahush.com/2009/10/21/amazing-pictures-pollution-in-china/; 2009 - 2011 ChinaHush is licensed under a Creative Commons License *Copyright:* Lu Guang;
b) **air pollution by heavy industries**; Quelle: china-digital-times *Copyright:* My Essentia com blog;
c) **In-Situ-Leaching**; Quelle: Web-Page Bellona *Copyright:* Andrej Ozharovsky;
d) **Entrance to waste disposal for radioactive waste from REE production in Bukit Merah** in Kledang mountains; built for 20 years storage of radioactive waste (14 Mrd years radioactive half-life); 1985 *Copyright:* Consumer Assciation Penang

Beitrag: Collector
Lizenz: Creative Commons (CC-BY-NC-SA) V.3.0

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What to do?

PETRA IV. NEW DIMENSIONS

- **Awareness:**

- **Workshop: Critical Materials and Life Cycle Management: The Example of Rare Earths – curse or blessing?** https://indico.desy.de/event/35655/overview
  - Life Cycle Assessment (LCA) and Recycling for permanent magnets
  - Certification and auditing for rare earth elements
- **REPM2023 in Birmingham** REPM 2023 (eventsair.com)
- **IFAST workshop:** https://indico.cells.es/event/1373/ Low emittance ring – Permanent magnets workshop


- **Recycling**

- Reuse and recycling of old undulators
- Include questions of RC already in design (eg. coating, glue …)

- **Certification**

- Development of a procurement scheme for sustainable magnets (in cooperation with other accelerator facilities)
- Cooperations with consultant is planned
- iFAST Workshop

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Sustainability in operation

- Technical components with less power consumption (eg. permanent magnets)
- Reduction of redundancies (eg. hot swap system for power supplies)
- **Optimization of operation parameters**
- Discussions for cooling agents and energy efficient cooling
- Waste heat
- **Reliability**
- **Efficient use of beamtime**
- **Reduction of traveling**
- **Data management**

DESY

- Technical monitoring
- Civil construction
- Waste heat usage

PETRA IV

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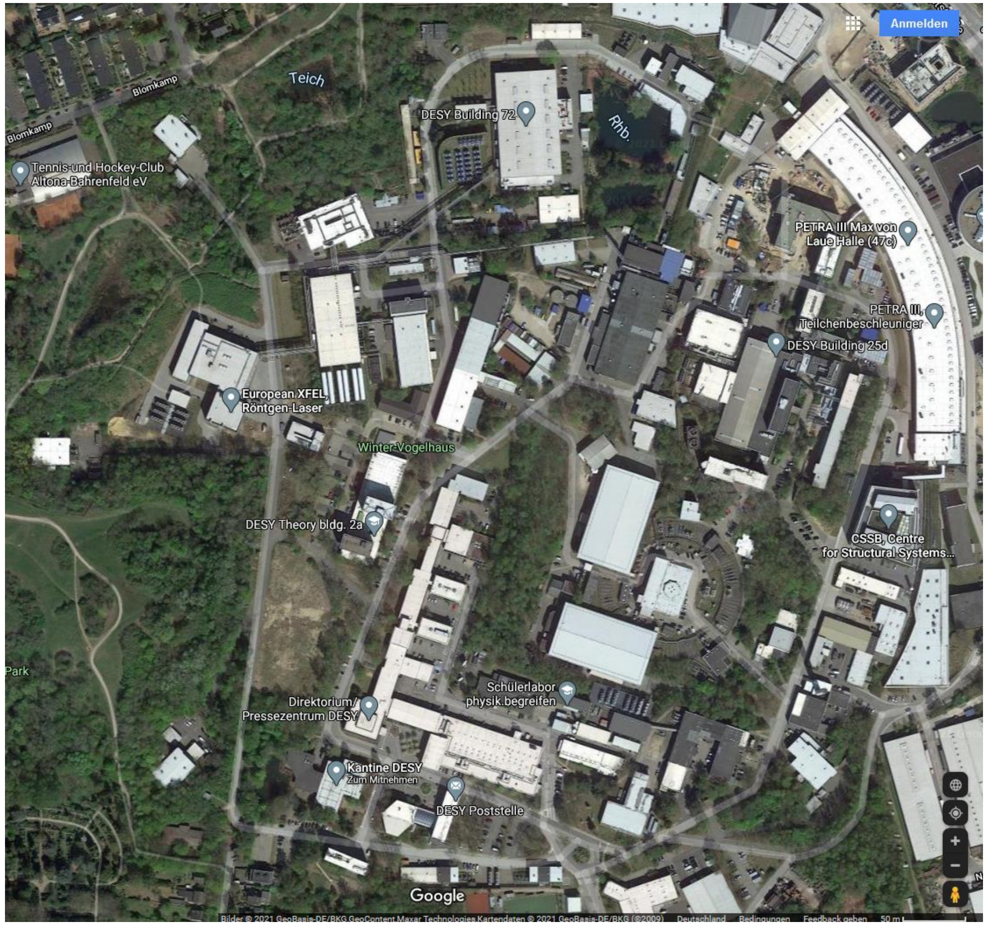
Heritage from PETRA I

PETRA I tunnel reused for Petra IV.



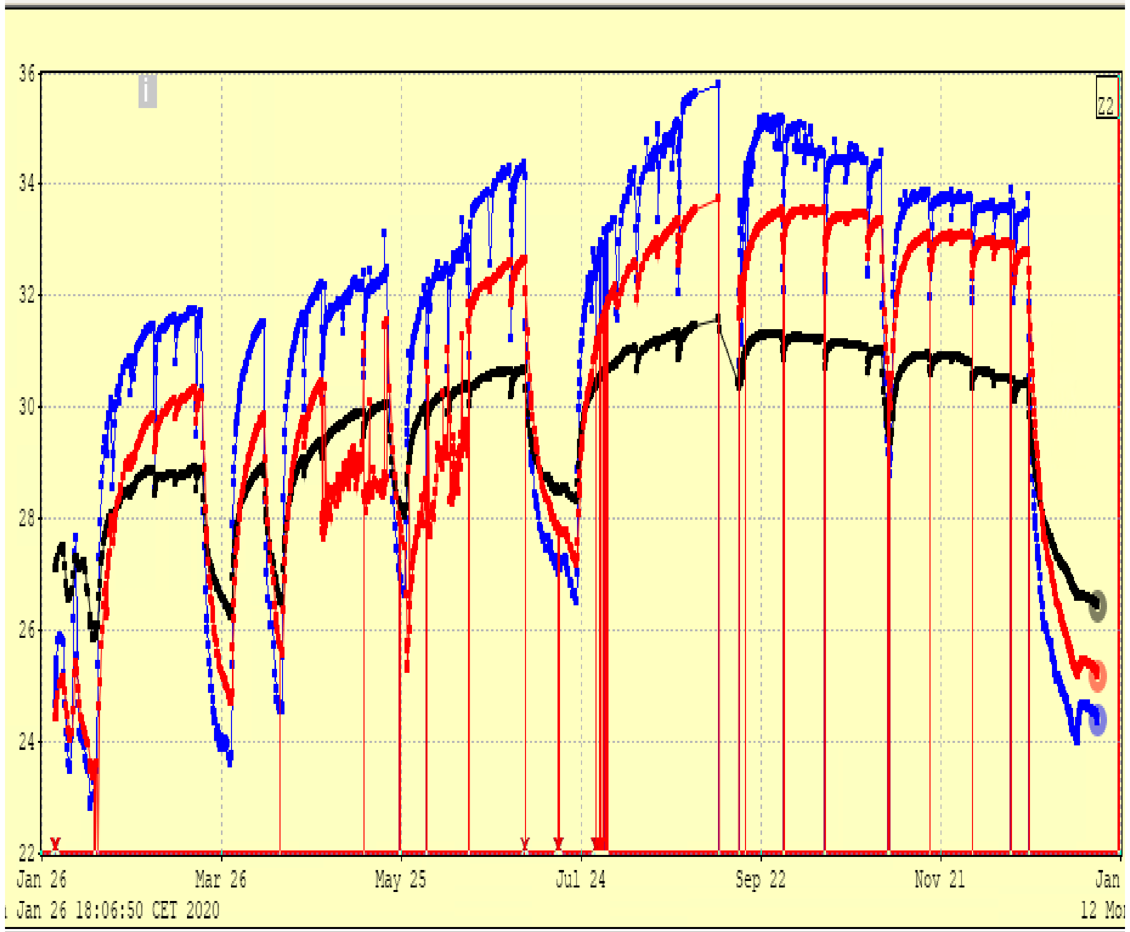
PETRA IV Tunnel

Outside the experimental halls the old PETRA I tunnel will be reused

- 6 old sections, 100 – 300 m long, in total ~1 km
- The old sections of the tunnel are below streets, buildings, a park.
- The tunnel is covered by 3 – 10 m of soil.

Tunnel temperature PETRA III

Heated and unheated sections



Black curve, 26° – 31° C: Concrete floor, OR59, air temperature regulated (30° C)
Red curve, 23° – 34° C: Concrete floor, SOR87, air temperature unregulated
Blue curve, 23° – 36° C: Air temperature, SOR85, air temperature unregulated

Tunnel Climatization today:

- Air (25° C) blown in every 300/600 m
- Cooling water inlet: 25° C

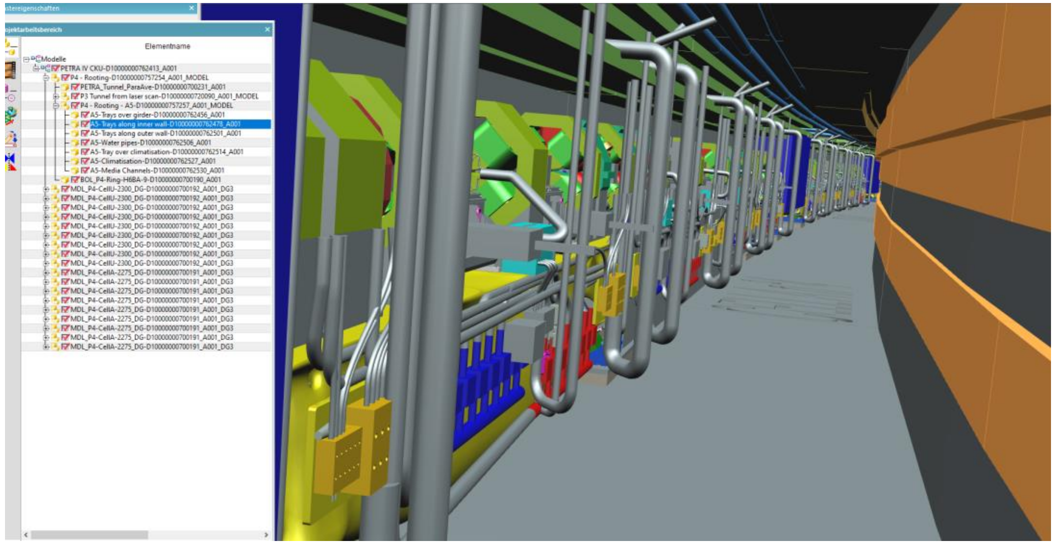
Temperature over one year

- Temperature difference between positions **up to 5°C**
- Operating schedule of PETRA clearly visible
- Summer and winter time visible

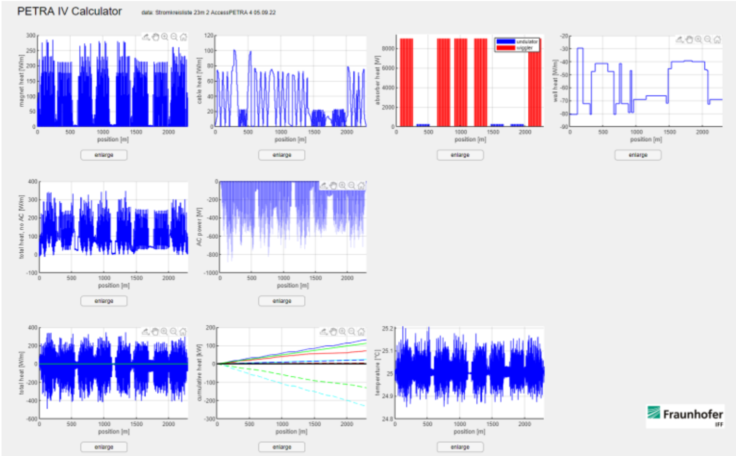
3D calculation of tunnel air and heat flows

Cooperation with Fraunhofer Magdeburg for CFD-simulation (fluid dynamic)

- **Digital Twin** of the tunnel in CAD (not yet completed)
  Single parts can be selected and hidden
  It can be rotated etc.
- A list with all consumer of electricity with their heat input
  (called **Stromkreisliste**)
- Including the cooling capacity and the position of air conditioners
- **Fluid dynamical simulations:**
  - Heat distribution also for corners and hidden places
  - Optimization for cooling and heating (in shutdowns)
  - Optimization of cabeling



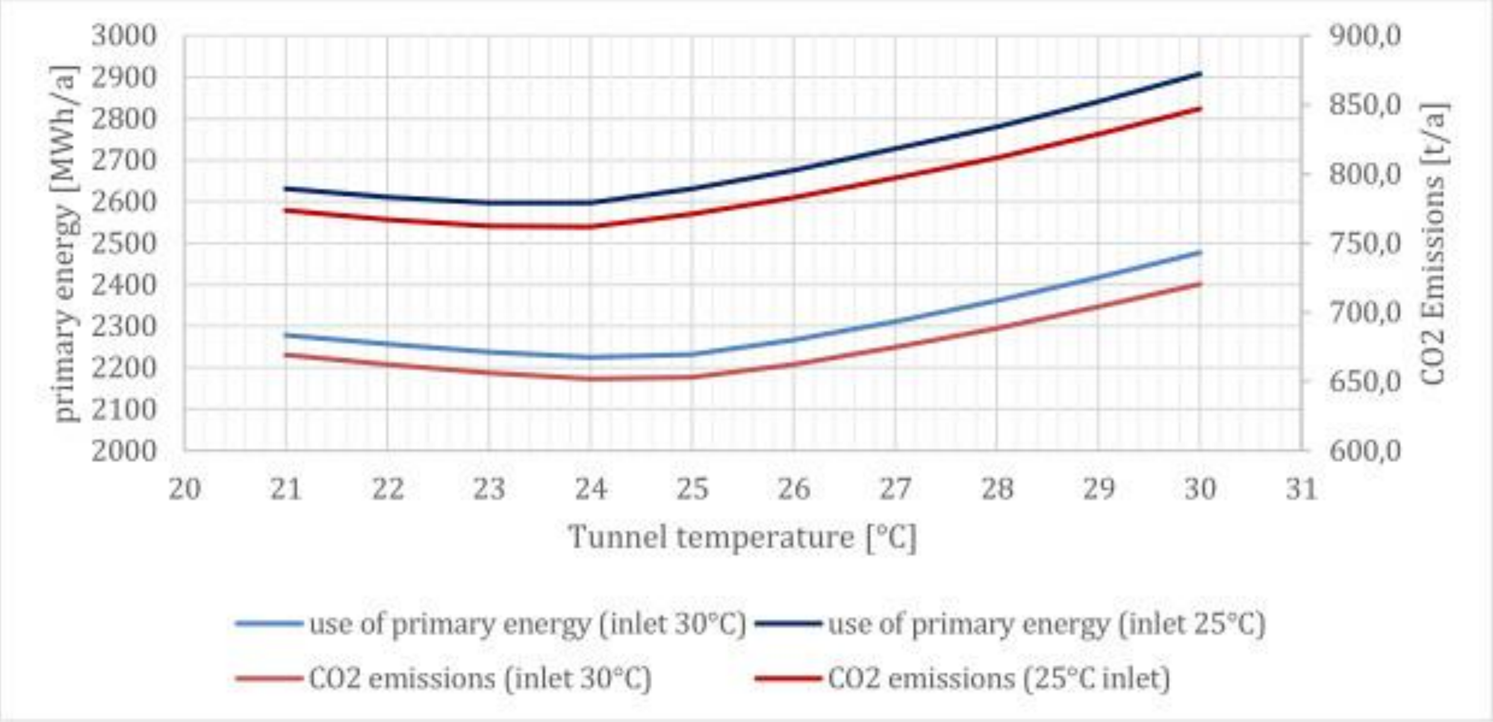
(Cedric Kula TAC)



screenshot of the app
and first test results
(R. Zimmermann)

Energy consumption for different tunnel temperatures

PETRA IV. NEW DIMENSIONS



Primary energy consumption and CO_2 emission for different tunnel temperatures and cooling water inlet temperatures with reference PETRA IV operation
(T. Warnecke „Report on thermal parameters of PETRA IV")

Including shutdowns, when we have to heat for a constant temperature.

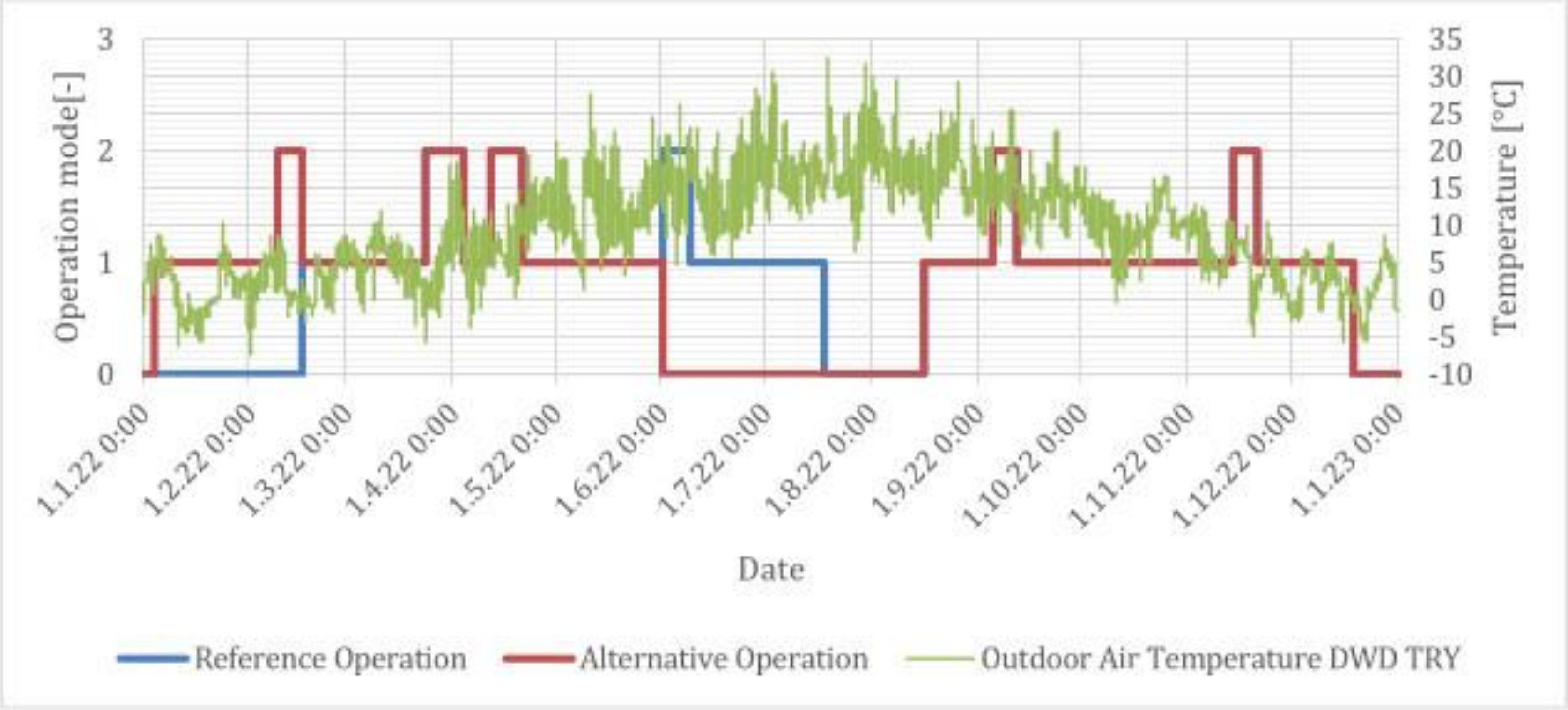
Optimal temperature in the tunnel are:

Water: 30°C
Air: 25°C

SUSTAIN ABLE DESY.

Temperature vs. operation mode

PETRA IV. NEW DIMENSIONS



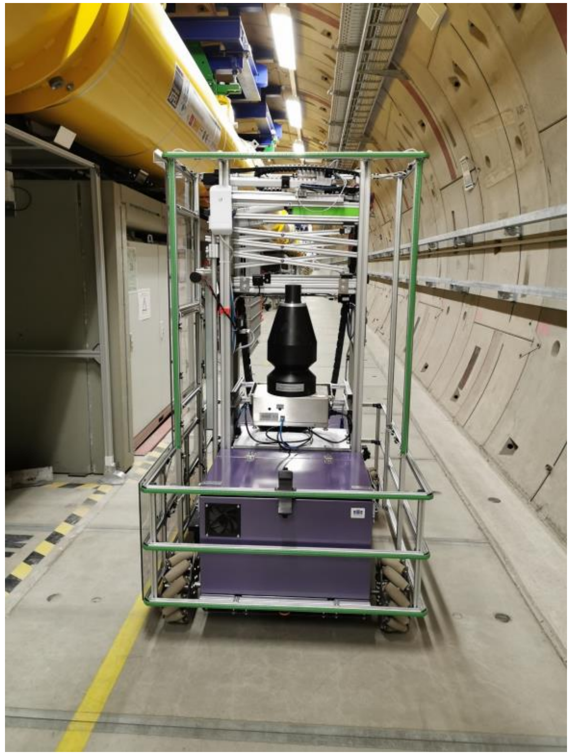
Reference and alternative operation schedule and outdoor air temperature
(T. Warnecke „Report on thermal parameters of PETRA IV“)

SUSTAINABLE DESY.

Reliability in operation

Use of robotics and telepresence of experts

PETRA IV. NEW DIMENSIONS



MARWIN2

MARWIN3

(Reinhard Bacher)

MARWIN: Mobile Autonomous Robot for Maintenance and Inspection

- Routinely used for radiation measurements with the EuXFEL accelerator switched on

Project Proposal RobotiX: Robotics and Immersive User Experience

- Versatile platform based on MARWIN3 that provides
  - Multiple sensors
  - Multi-axis manipulators
- Immersive remote control interface using mixed reality technologies
- Project partners: Hochschule21, HAW, UHH, DESY

KAI Kooperation für Anwendung und Innovation der HAW Hamburg und DESY

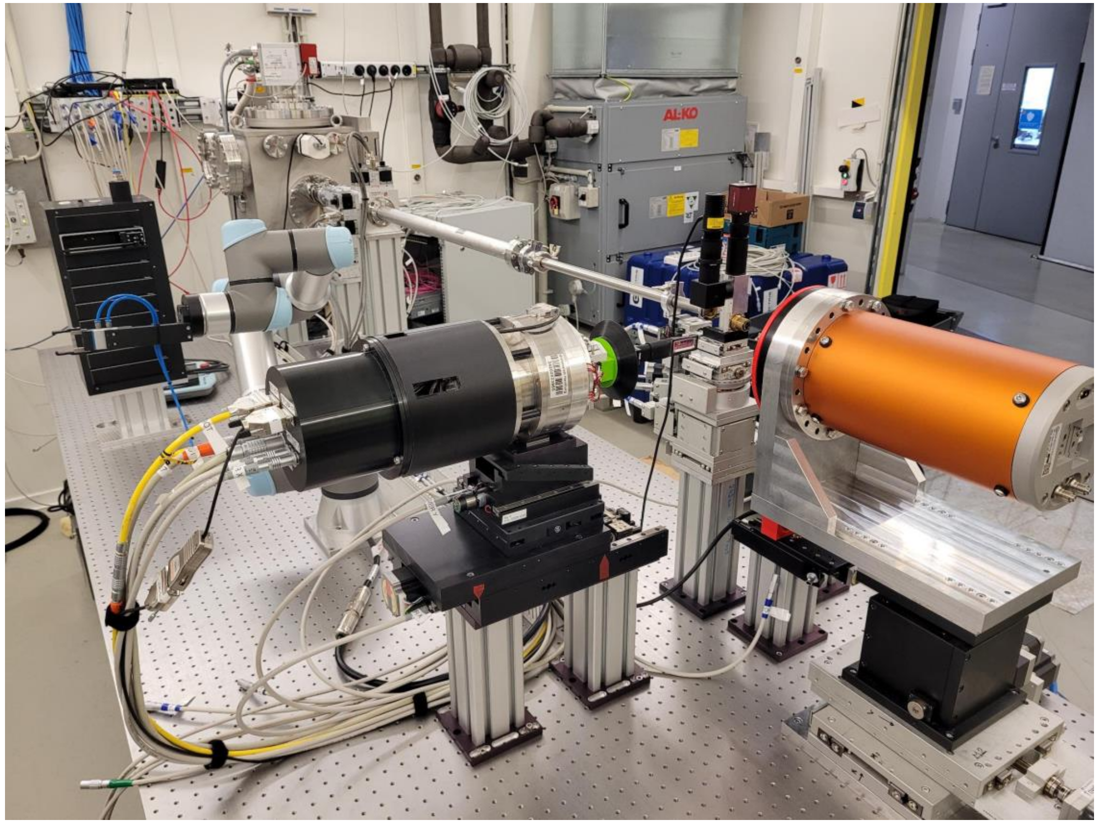
SUSTAINABLE DESY.

Efficient use of beamtime – every photon counts

PETRA IV. NEW DIMENSIONS

HiPhax: Highly automated pharmaceutical screening beamline for room temperature measurements

- Designed for high-throughput pharmaceutical screening at cryogenic temperatures and room temperature
- >1000 samples/24 h
- Goal: Fully automatic, AI- supported data collection
- Multicrystal samples holders (Si-chips) for highest throughput
- Robotic exchange of chips
- Hotel for chip storage
- Sample delivery format compatible with installation at SPB/SFX at EuXFEL



First successful test experiments in June/July 2022 at beamline P09 at PETRA III

Hardware installation of automatic sample changer: HIR3X milestone M1.1

SLAC HIR³X SUSTAINABLE DESY.

Petra IV. - Remote access – high-troughput MX

PETRA IV. NEW DIMENSIONS

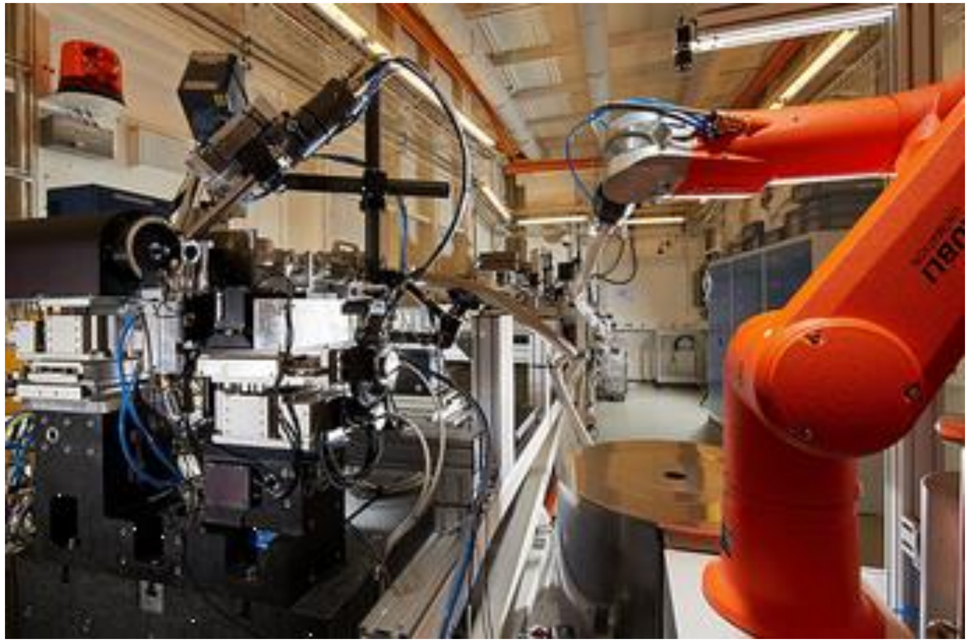
Petra IV. will enable remote access for mature and highly standardizes X-ray techniques

Prime example P11 beamline PETRA III:

- Experienced users have the possibility to collect data remotely
  - No travel of persons, just sending samples
  - Access via remote session from internet browser
  - Guidelines for remote access (safety aspect)
  - Need to register for access

If all scheduled beamtimes would be remote (example):

- Users just from EU (only single P11 beamline)
- Ca. 17 tons CO_2 savings from flight travels / year (https://www.carbonfootprint.com)



The technical equipment at PETRA III's P11 beamline includes a robotic arm that can execute fully automated sample changes

(Johanna Hakanpää)

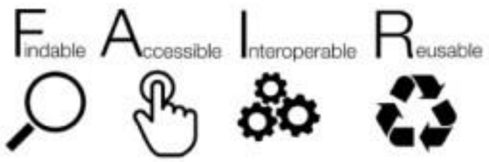
SUSTAIN ABLE DESY.

Keeping Data

Value of data

- Academic tradition
- 'Good scientific practice'
- Sometimes mandated by law (USA)?
- Typically archive all 'raw' data for 10 years
- Including data known to be 'dud'
- A 'nice to have' or 'must have'

- Keeping raw data costs significant money (M€) and energy (MW)
- Keeping all data for lots of experiments becomes expensive very quickly
- Facility cost or user's own cost
- Sustainability?



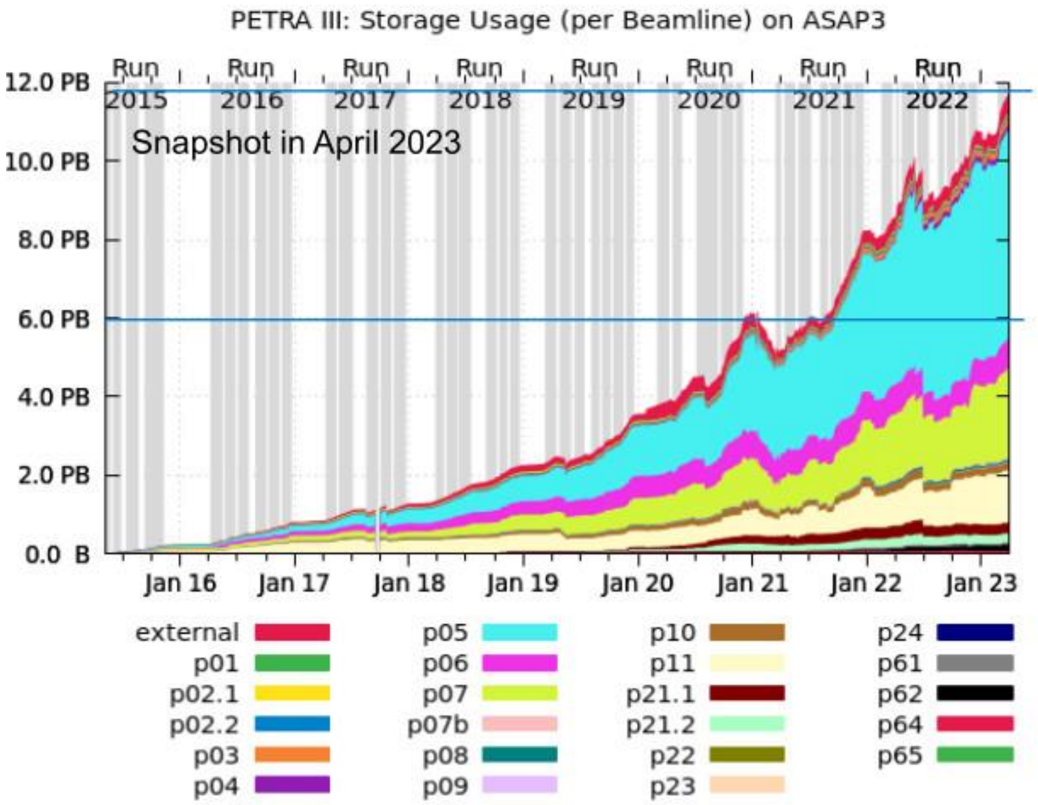
Anton Barty
Twenty-Sixth Congress and General Assembly of the International Union of Crystallography

Data management

A snapshot of the status quo

PETRA IV. NEW DIMENSIONS

- Data policy
  - Data on disk for 180 days after measurement (was :180 days after last access)
  - Data migrated to tape after 180 days
    - retention on site (dCache), dual tape copy
    - 4.5 PB ingested to GPFS in past 12 months
    - 6 PB/year archived to tape
    - 12 PB tapes/yr with dual copy (€20K/PB/10YR)
- Usage highly variable between instruments
- Time to analyse data often limits publication rate
  ~2 years from measurement to publication
- Hardware typically has a 5 year lifetime
  Budget for regular replacement



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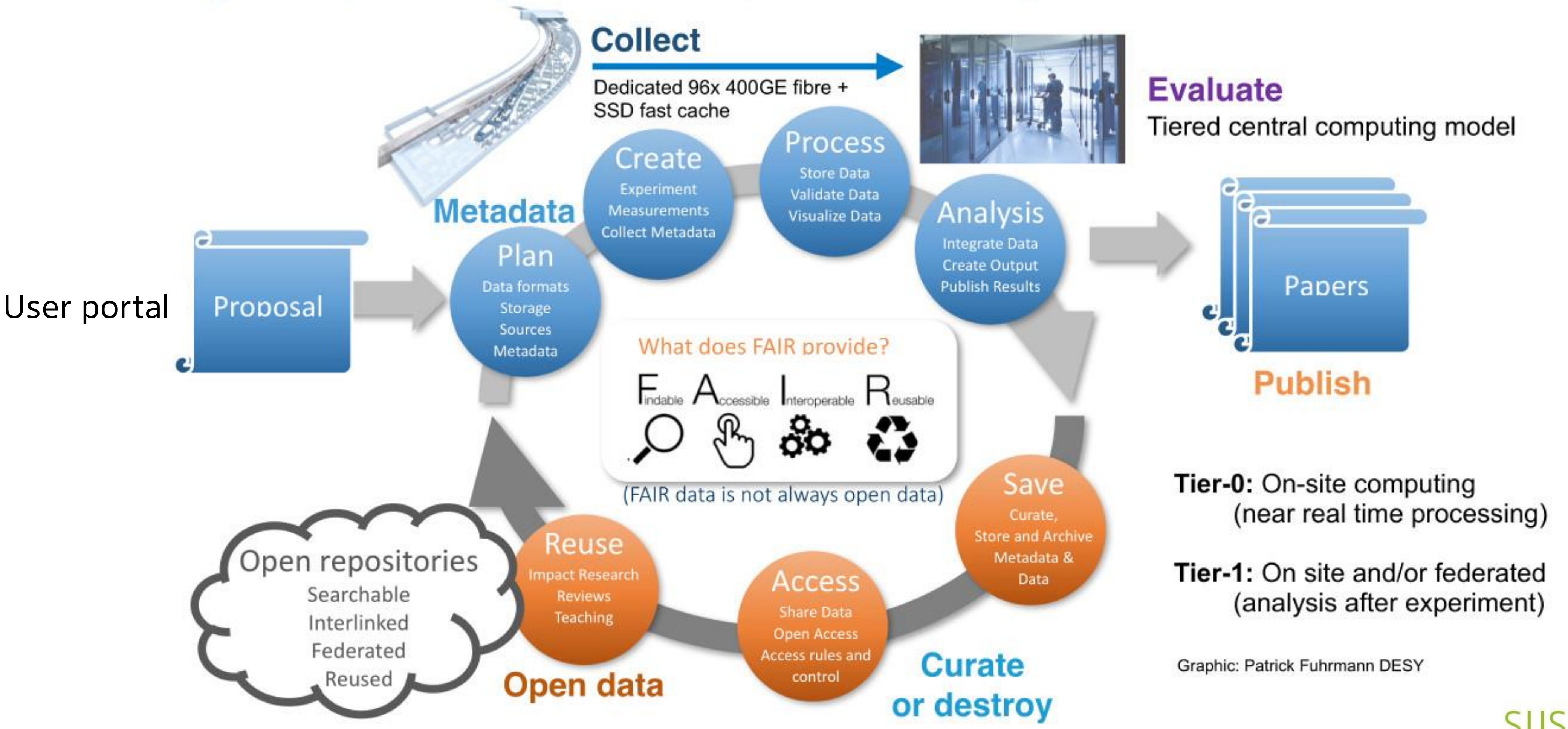
SUSTAINABLE DESY.

Petra IV. will offer services for the complete data life cycle

PETRA IV. NEW DIMENSIONS

Data management by the facility



Tier-0: On-site computing (near real time processing)

Tier-1: On site and/or federated (analysis after experiment)

Graphic: Patrick Fuhrmann DESY

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TWENTY-SIXTH CONGRESS AND GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF CRYSTALLOGRAPHY

SUSTAINABLE DESY.

DESY

- Technical monitoring
- Civil construction
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PETRA IV

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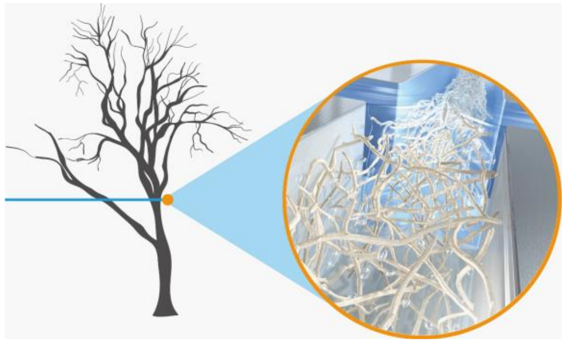
- **Research**

Petra IV. - Research for sustainability

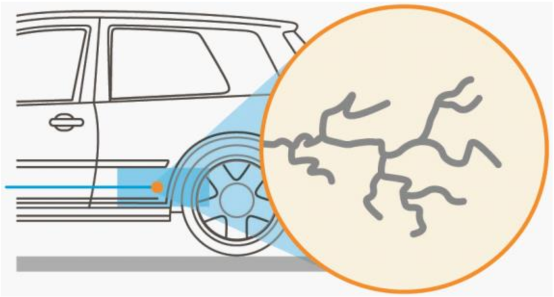
What makes an accelerator sustainable is the research we do with it.

- Future trends: research for sustainable technology
- New experimental hall with 18 beamlines
- New access and business model to achieve faster access to the facility for industry and to avoid traveling



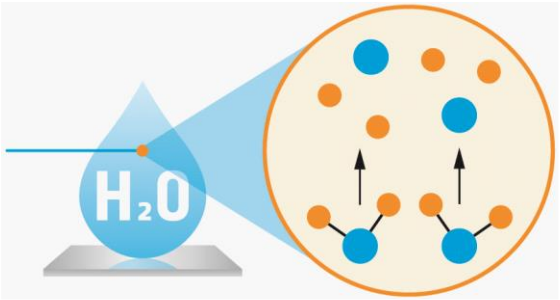
Green hydrogen

- Processes for generating hydrogen fuels are not sustainable
- By using PETRA IV to examine water-splitting reactions in nature and understand at the atomic level how they progress
- We can develop more efficient processes



Plastic alternatives

- Cellulose nano-fibres derived from wood make for a sustainable version of our everyday plastics
- Using the light from PETRA IV, the production process can be followed in much greater detail and 100 times faster than before



Long-lasting solar cells and new batteries

- Optimize the electronic structure of materials of solar cells and batteries by using atomic-level imaging and spectroscopy

Thank you for your attention!

Contact

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