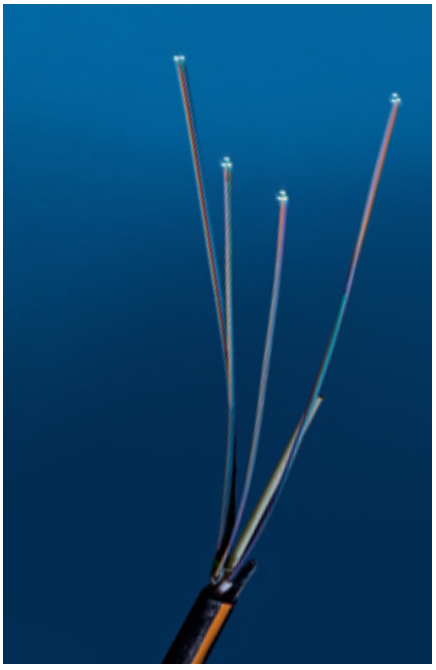
METAS in 2022

METAS
Your reference.



Cover picture: Fibre-optic cables with strong magnification (see article on pages 16/17)

Legal notice

This report provides an overview of the activities of METAS in 2022.

Information on other annual reports

Finances:
Pages 26 and 27 of this report contain information on the annual financial statements of METAS as at 31 December 2022. The 2022 annual accounts have been published together with the auditor's report at www.metas.ch.

Publisher/editor:
Federal Institute of Metrology METAS
Customer Service and Communication
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Text editor:
Sabine Graf, Bern
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Design and production:
Casalini Werbeagentur AG, Bern
www.casalini.ch

Languages:
German, French, Italian;
English online only

Image credits:
METAS, unless otherwise stated

Edition:
May 2023

Editorial

In a strong position to face the challenges of tomorrow

The Federal Institute of Metrology METAS is involved in international metrology organisations to be able to continue to complete its tasks as the federal competence centre for all matters relating to high-quality measurement. By networking with colleagues from other national metrology institutes on technical committees and working with them, we can face the challenges of technological change, which even metrology cannot escape.

Over the past year, we continued with the systematic implementation of our METAS 2025 vision. Newly created structures will allow us to meet the requirements of our clients and customers even more effectively in future. Thanks to our newly devised research and development programme, we will be able to be counted among the world's leading metrology institutes in the future, too. The new Customer Service and Communication division is working to make METAS's activities more tangible and better known to customers and the general public, because we all come into contact with the subject of measurement on a daily basis, whether we need to rely on the fact that the weight of products matches the weight written on the pack or that our electric meter at home is showing the amount of energy actually consumed.

I am delighted to give you an insight into some of METAS's varied tasks, services and research projects in this annual review.

Dr Philippe Richard
Director of the Federal Institute of Metrology METAS

Foreword

Research and development are everything

Research and development are a key part of the strategy of a national metrology institute. In order for METAS to be able to remain at the leading edge with its metrological infrastructure and its services in future, the right priorities need to be set when defining the orientation of research and development.

The Institute Council (from left): Prof. Dr Sonia Isabelle Seneviratne; Dr Ursula Widmer, Vice President; Dr René Lenggenhager; Dr Matthias Kaiserswerth, President; Roger Siegenthaler; Prof. Dr med Alessandra Curioni-Fontecedro.

The launch of the 2023+ research and development programme (FP23+) will create the conditions required for METAS to continue to provide a modern metrological infrastructure in the future and to retain its position as the "best small metrology institute" in international competition.

The programme is divided into five topics: 1) Energy and mobility; 2) Health and life sciences; 3) Fundamentals and new technologies; 4) Industry; 5) Environment, climate and natural resources. These topics are broken down into 18 specific areas of action. METAS scientists can propose projects in each area of action and apply for research funding. It is important to note that, in these areas of action, the challenges can usually only be addressed by interdisciplinary teams comprising members from different divisions of METAS. You can read more about FP23+ on pages 10 and 11 of this report.

In November 2022, the Federal Council elected Roger Siegenthaler as a new member of the Institute Council for the remaining term of office until the end of 2023. With the addition of Mr Siegenthaler, the Institute Council has gained a proven specialist. He already has direct experience of METAS, since he worked at METAS as a technical expert many years ago. He now runs a microtechnology company. We are looking forward to working with Mr Siegenthaler.

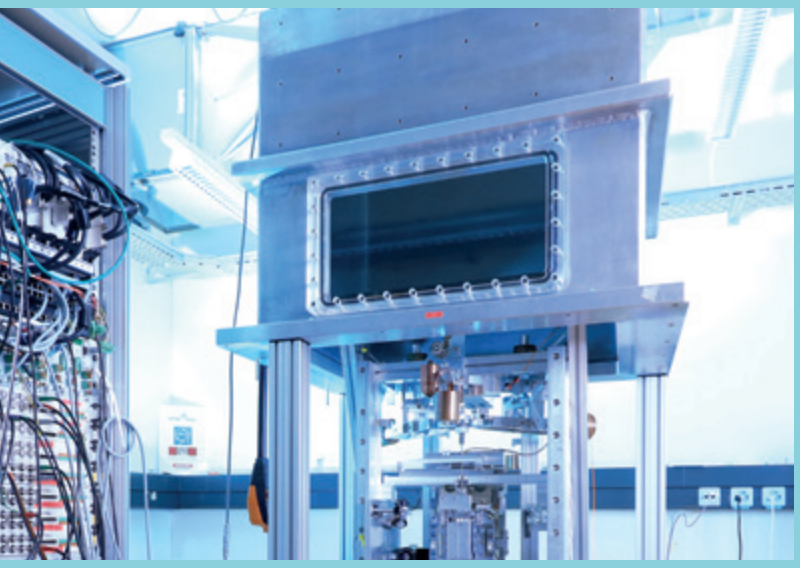
In December, the Institute Council also selected Dr Fabiano Assi as the new Head of the Physics Department and member of the Executive Board as of 1 January 2023. I am delighted that we were able to appoint an internal specialist to this position. My colleagues and I are excited at the prospect of continuing with the strategic management of METAS together with the newly constituted Executive Board.

The Institute Council
Dr Matthias Kaiserswerth, President

Highlights

In 2022, the Federal Institute of Metrology METAS experienced a number of highlights that attracted attention, and not only for scientific and metrological reasons.

26 January 2022



Following the successful development of the Kibble balance, METAS participated in the international comparison to realise the mass. METAS thus secured its access to the exclusive club of metrology institutes that are in a position to realise the kilogram. Find out more on pages 16 and 17.

13 June 2022

As a token of appreciation and to say thank you for their hard work under difficult circumstances during the COVID-19 pandemic, all staff members were invited to an excursion in the Bernese Oberland on 13 June 2022.

15 September 2022

In partnership with the University of Fribourg, METAS invited guests to a symposium in Wabern on 15 September 2022 entitled “Dynamik in der Metrologie für den Strassenverkehr” (“Momentum in metrology for road traffic”). Around 100 experts discussed issues relating to changes in private transport, focusing particularly on automated driving and the use of artificial intelligence, but also on topics such as data recording and digital evidence investigation in the event of an accident.

19 September 2022

© Federal Mint Swissmint

Originally an old mint with a mint gate on Gerbergraben in Bern – now the Federal Institute of Metrology METAS with a total of 15 metrological laboratories and 3 technical divisions in Wabern. On 19 September 1862, the Federal Council decided to establish a federal verification laboratory and thereby laid the foundation for today’s institute. 160 years later, it is hard to imagine that the cantons had held full responsibility for metrology until then. At the time, the Federal Council was persuaded to change its mind by a report by physicist and astronomer Heinrich Wild of the University of Bern, who recommended to the Federal Department of Home Affairs in 1861 that a federal standard verification laboratory should be set up and the mass standard should be thoroughly reformed.

1 January 2023

The two national reference laboratories – the Reference laboratory for food-borne viruses and the Reference laboratory for genetically modified organisms in food – moved from the Federal Food Safety and Veterinary Office (FSVO) to the Federal Institute of Metrology METAS as of 1 January 2023. This move meant that seven new employees joined METAS. On 16 November 2022, the Federal Council announced the transfer and the corresponding change to the Ordinance on the Federal Institute of Metrology (METASO). The laboratories are merging to set up a national centre for analytical competence and references in the field of food safety and nutrition. See pages 14 and 15 for more information.

METAS in figures

Implementation of the Metrology Act

METAS ensures compliance with metrology law in Switzerland.

Here are some of the measuring equipment and measuring procedures tested.

Tests by the cantons

48 500 balance verifications

21 700 verifications of measuring instruments for liquids other than water

14 000 controls of pre-packaged goods / tested lots

Tests by the verification laboratories

1 100 000 electricity meters / instrument transformers

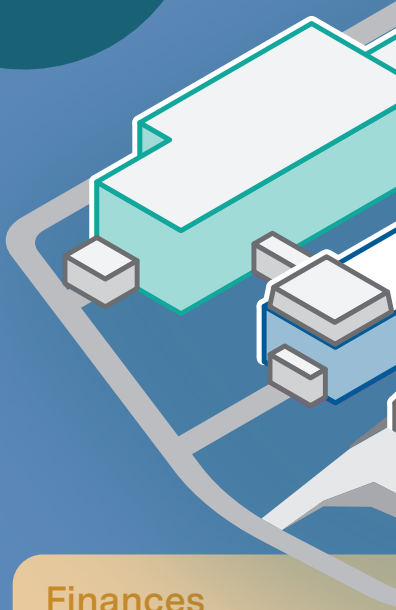
Tests and audits by METAS

3500 breath alcohol measuring instruments

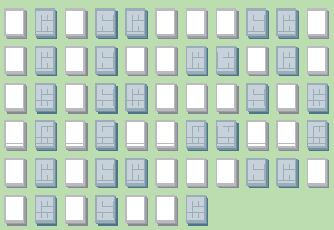
180 audits and inspections conducted

4000 road traffic measuring instruments (red light and speed measuring equipment)

Languages



Research and development



62 scientific publications

3 patents applied for

Finances

53.1 m.
Revenue

Apprentices

- Platform development computer scientist
- Electronics technician
- Mediamatics specialist
- Business management internships for the commercial employee apprenticeship
- ICT specialist
- Physics laboratory technician
- Chemical lab technician

Employees

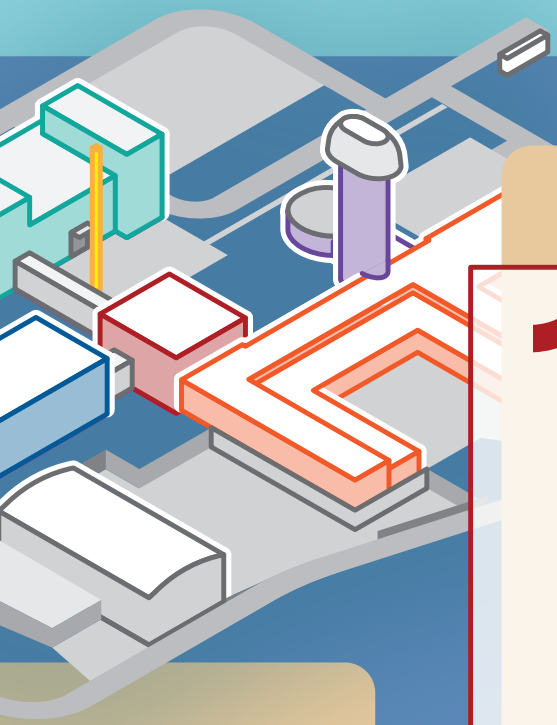
20 apprentices

6 university interns

37 ployees

♀ **19.4 %** **women**
67.4 % working part-time

♂ **80.6 %** **men**
31.4 % working part-time



Services

6 400
measuring instruments

15 metrological laboratories

- **4 laboratories in the Electricity sector:** DC and Low Frequency | Electrical Energy and Power | High Frequency | Electromagnetic Compatibility
- **3 laboratories in the Length, Optics and Time sector:** Length, Nano- and Microtechnology | Optics | Photonics, Time and Frequency
- **3 laboratories in the Mechanical Quantities and Ionising Radiation sector:** Mass, Force, Pressure and Vibration | Flow and Hydrometry | Ionising Radiation
- **5 laboratories in the Chemical and Biological Metrology sector:** Gas Analysis | Particles and Aerosols | Inorganic Analysis and References | Organic Analysis and References | Biological Analysis and References

- **1 Verifications and Tests sector with three teams:** Traffic | Acoustics | Audiometry
- **1 Chemical Tests and Consultancy sector with two teams:** Analysis / Tests | Consultancy
- **1 Monitoring Networks sector with three teams:** Quality and Maintenance | Software | Interventions and Installation

3 technical divisions

1.2 m. Profit
55.0 % Level of self-financing

The 2023+ research and development programme

Due to technological progress and new societal challenges, metrological principles also need to evolve constantly. Research and development are therefore crucial to METAS – they form the basis for sustainable further development.

Trustworthy and comparable measurements form the basis of our modern society, as today's technologies could not exist without reliable metrology. Metrology must therefore evolve at the same pace as technological developments.

The 2023+ research and development programme (FP23+) provides the guiding principles for research at METAS over the next few years. Its aim is to ensure that METAS can continue to provide a modern metrological infrastructure in Switzerland. FP23+ organises the research activities into the following five topics:
1) *Energy and mobility,*
2) *Health and life sciences,*
3) *Fundamentals and new technologies,*
4) *Industry and*
5) *Environment, climate and natural resources.*

METAS experts from the relevant technical fields performed an environmental analysis in each of these five topics, taking into account scientific and technological progress, the Federal Government's strategic guidelines and the trends and expectations of stakeholders. The metrological areas of action were then identified on this basis.

The five topics and their areas of action

The topic *Energy and mobility* develops metrological solutions to issues relating to the energy transition and addresses the metrological problems of automated driving.

The topic *Health and life sciences* focuses on comparable laboratory measurements using new analytical and digital methods, and their related uncertainties.

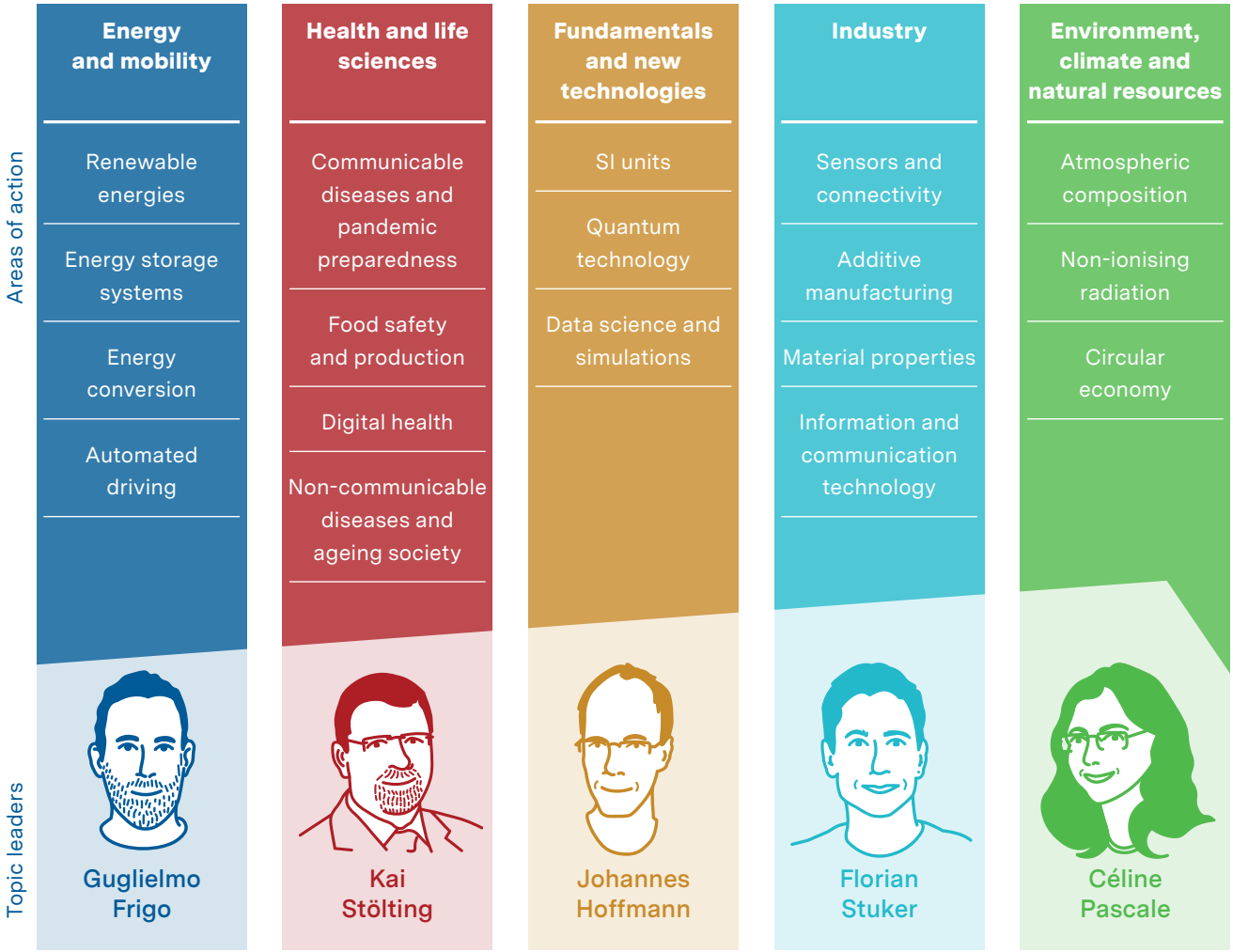
The aim of the topic *Fundamentals and new technologies* is to prepare and initiate new primary realisations of the SI units. The two new fields of quantum technology and data science are also to be firmed up and developed.

The topic *Industry* covers questions relating to the calibration of sensor networks, the analysis of new materials and 3D printing procedures. This topic also addresses measurement technology issues in the field of information and communication technologies.

Finally, the topic of *Environment, climate and natural resources* intends to contribute to a better understanding of the composition of the atmosphere. Another aim is to meet the metrological challenges in the field of non-ionising radiation and in the circular economy.

Overview of the research and development topics

Five topics with a total of 18 areas of action will guide research and development at METAS over the next few years.



The 18 areas of action in total define the content that is to be worked on in research and development at METAS in the next three years. In the first stage, the areas of action will be firmed up by relevant project proposals from the laboratories, then the proposals will be evaluated and approved by the topic experts.

European Partnership on Metrology (EPM)

The European Partnership on Metrology (EPM) was launched in 2021 as part of the Horizon Europe research programme. The EPM aims to create the financial and institutional framework conditions enabling metrology to successfully meet the new challenges facing society and industry. Research is to focus on the topics of the Green Deal, health, digitalisation, integrated European metrology, standardisation and exploration. Since Switzerland is not associated with Horizon Europe, METAS is an EPM member with no authority to manage projects; the Swiss partners are to be financed directly by Switzerland.

Energy and mobility

Research projects to support the energy transition

METAS is making important contributions to the energy transition by developing the metrological infrastructures and measuring procedures required.

The European Partnership on Metrology (EPM) is a funding programme that aims to create a sustainable and effective world-class measurement system by 2030 (see page 11). In the area of electricity, the funding programme is to enable the establishment of a reference measuring procedure harmonised throughout Europe for the electricity grids of the energy transition.

Challenges relating to electrical energy in wind turbines

METAS is tackling the practical challenge of calibrating nacelle test benches for wind turbines. The nacelle is the cuboid-shaped housing on top of the wind turbine's tower that is connected to the spinning rotor. It converts mechanical energy into electrical energy.

Since 2020, METAS has been participating in the "WindEFCY: Traceable mechanical and electrical power measurement for efficiency determination of wind turbines" project. The project was launched as part of the European Metrology Programme for Innovation and Research (EMPIR). It aims to improve the efficiency determination of wind turbines. Trustworthy and efficient measurement is essential to optimise the efficiency of wind turbines. If a modern wind turbine produces a total output of 9 megawatts, even a deviation of 1%, for example, makes a significant difference, because 1% is enough to supply 175 households.

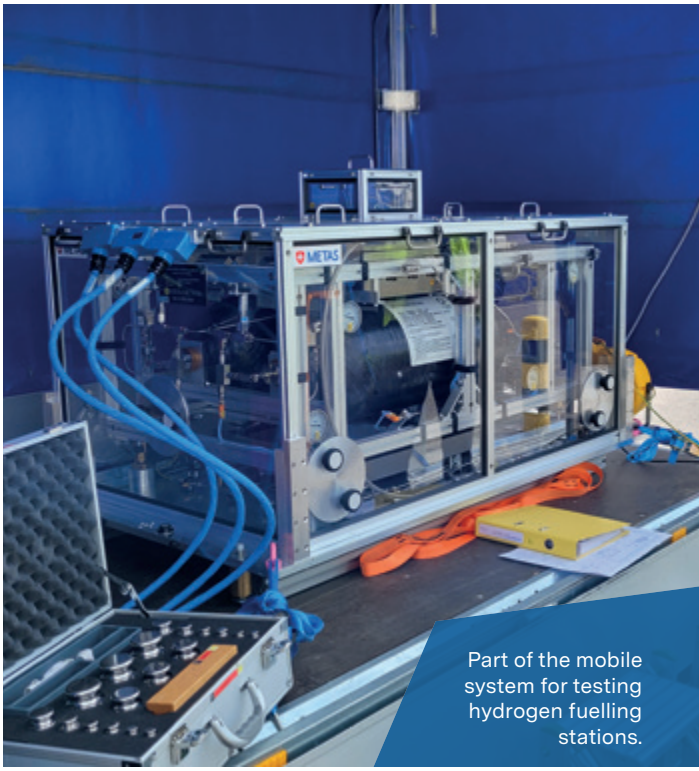
Nacelle test bench: wind turbine being tested. (© RWTH)

Together with other metrology institutes, METAS is helping with efficiency measurements on the nacelle test benches of the wind turbines at the Fraunhofer Society and RWTH Aachen University.

Measuring for future mobility: verifying hydrogen fuelling stations

Filling up our own vehicle is almost a daily activity, in which we complete a commercial transaction at the same time as refuelling. A measuring system determines the quantity of fuel supplied by the pump, which we ultimately have to pay for. To ensure that pumps measure reliably and that the quantity of fuel paid for matches the quantity received, pumps are verified regularly.

As, in recent times, hydrogen is increasingly being used as a fuel for vehicles, the corresponding fuelling stations are required – and these must be verified too. METAS has developed a mobile system for testing or verifying hydrogen fuelling stations. It is one of only a few systems worldwide that make these types of measurements possible, and can therefore guarantee trust in a correct transaction. In summer 2022, METAS was commissioned by a large international company to verify a hydrogen fuelling station in the Netherlands with its mobile reference measuring system for hydrogen. The METAS team therefore travelled to Emmen in the Netherlands and performed the measurements successfully on site – sales at this fuelling station could be approved within a single day.



Part of the mobile system for testing hydrogen fuelling stations.

EPM 2022 call for proposals

In 2022, the European Union's contribution to the EPM call amounted to EUR 45 million. METAS is participating in a total of six financed projects covering various topics. They range from new optical calibration methods for new lighting systems to hydrogen flow measurements in gas networks and storage facilities.

Health and life sciences

Fast, sensitive, precise: better measurements for health

In addition to metrological services, METAS also offers analytical services and supports European research consortia as well as the enforcement laboratories. At the beginning of 2023, the two national reference laboratories – the Reference laboratory for food-borne viruses and the Reference laboratory for genetically modified organisms in food – were integrated into METAS.

High-quality measurements are essential to diagnose diseases. The more sensitive these measuring methods are, the faster rare pathogens can be identified and time-critical diseases treated. Detection methods such as the digital polymerase chain reaction (dPCR) are central to this. The method permits replication of rare genetic template materials, thus making diagnosis easier. Quantifying dPCR has been in use at METAS for several years.

Faster and more accurate: sepsis diagnostics in the SEPTIMET project

Sepsis is a life-threatening inflammatory reaction whose treatment success depends, among other things, on the time to diagnosis. As part of the SEPTIMET project, researchers developed reference systems for diagnostic tests and support diagnostics manufacturers in developing rapid tests for sepsis diagnostics. In this context, METAS contributed to the development and application of molecular assays for dPCR-based pathogen detection. In addition, the institute developed methodological and conceptual proposals for the implementation of ISO regulations, with a focus on metrological traceability.

Sampling for *Vibrio* detection.

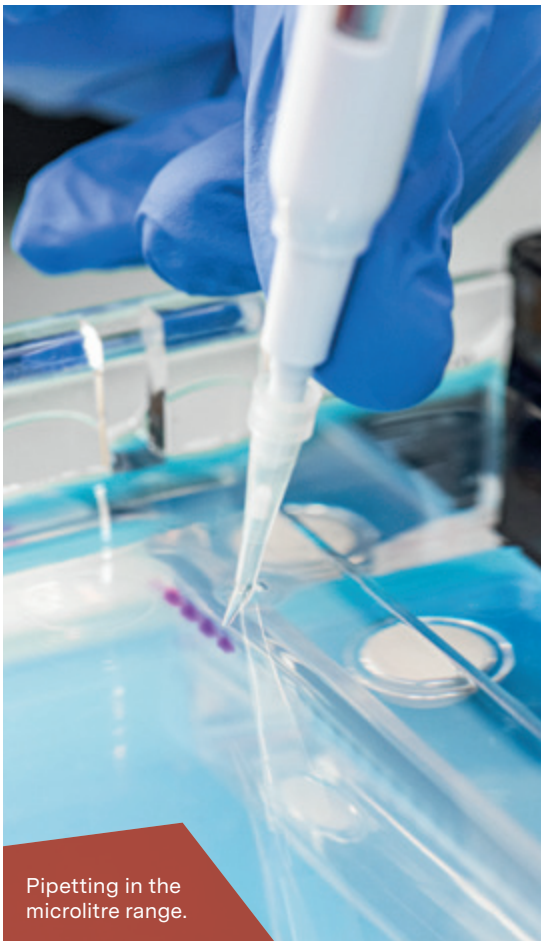
Highly accurate and sensitive: collaboration to detect *Vibrio*

Some human-pathogenic bacteria of the *Vibrio* genus are found in warm coastal seawater. Anyone who consumes seafood and fish contaminated with *Vibrio* can develop gastrointestinal inflammation (gastroenteritis). It is therefore crucial that *Vibrio*-contaminated seafood can be detected. Here, both the species identification and its abundance are of relevance. In cooperation with the biological laboratories of the Federal Food Safety and Veterinary Office (FSVO), *Vibrio* have been identified in DNA extracts using modern high-throughput sequencing methods. To this end, METAS designed and characterised a series of reference materials to detect and quantify *Vibrio* using dPCR.

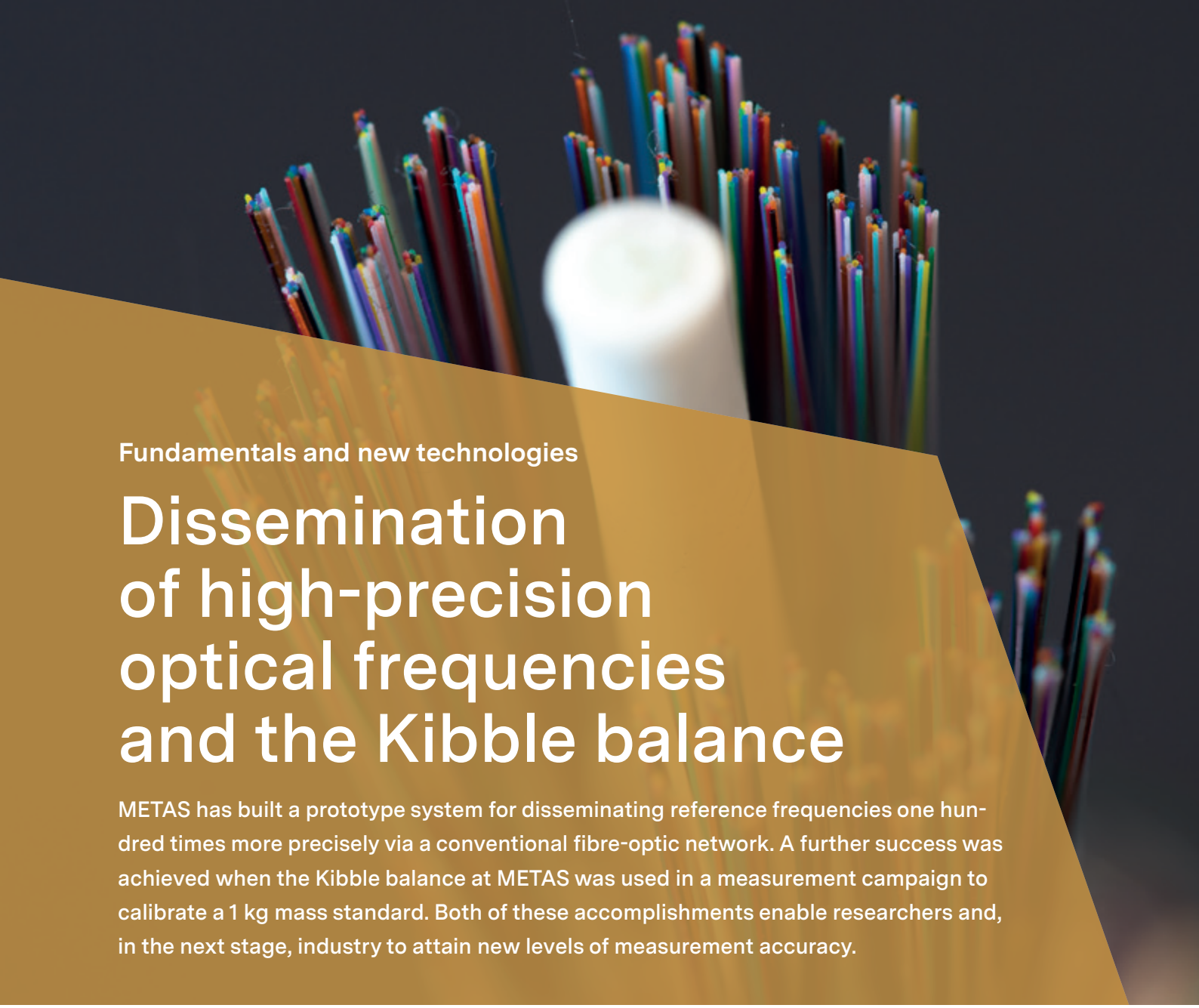
New services: two additional national reference laboratories join METAS

Cantonal laboratories and consumer protection offices check food on the Swiss market for safety and legal compliance. In order to be able to carry out the investigations necessary for such checks, comparable measurement methods are required. This is ensured by the national reference laboratories. They ensure that the analyses are carried out according to internationally standardised methods and thus make an important contribution to food safety.

Since 1 January 2023, the Reference laboratory for food-borne viruses and the Reference laboratory for genetically modified organisms in food have been integrated into METAS. The two reference laboratories were transferred to the newly created laboratory for biological analysis and references and will continue to do their previous activities in the future. Among other things, they develop and validate new detection methods and contribute to investigation campaigns with their own analyses.



Pipetting in the microlitre range.



Fundamentals and new technologies

Dissemination of high-precision optical frequencies and the Kibble balance

METAS has built a prototype system for disseminating reference frequencies one hundred times more precisely via a conventional fibre-optic network. A further success was achieved when the Kibble balance at METAS was used in a measurement campaign to calibrate a 1 kg mass standard. Both of these accomplishments enable researchers and, in the next stage, industry to attain new levels of measurement accuracy.

Together with research groups from the University of Basel and from ETH Zurich, as well as the SWITCH foundation, METAS has built a prototype system that can be used to transmit high-precision optical frequencies hundreds of kilometres via a conventional fibre-optic network. This makes it possible to send the reference frequency of the atomic clocks at METAS via the fibre-optic network to research laboratories in Basel and Zurich. An ingenious noise correction technique corrects any interference caused by external influences such as temperature fluctuations, vibrations or even seismic events. This network's special feature is that the optical reference frequency is fed into an unused frequency channel far away from normal data traffic. The optical frequency can therefore be transmitted together with conventional data traffic in the same fibre without any interference between the two. The project was financed by the Swiss National Science Foundation.

High-precision spectroscopy: one hundred times more precise

Thanks to such transmission, researchers at the University of Basel and at ETH Zurich have access to a new high-precision METAS reference frequency that enables them to attain new levels of measurement accuracy – particularly in the field of high-precision spectroscopy. The new frequency is roughly one hundred times more precise than the previous one, making it possible for the researchers to study new physical phenomena. But high-precision optical frequency transmission is also crucial for metrological

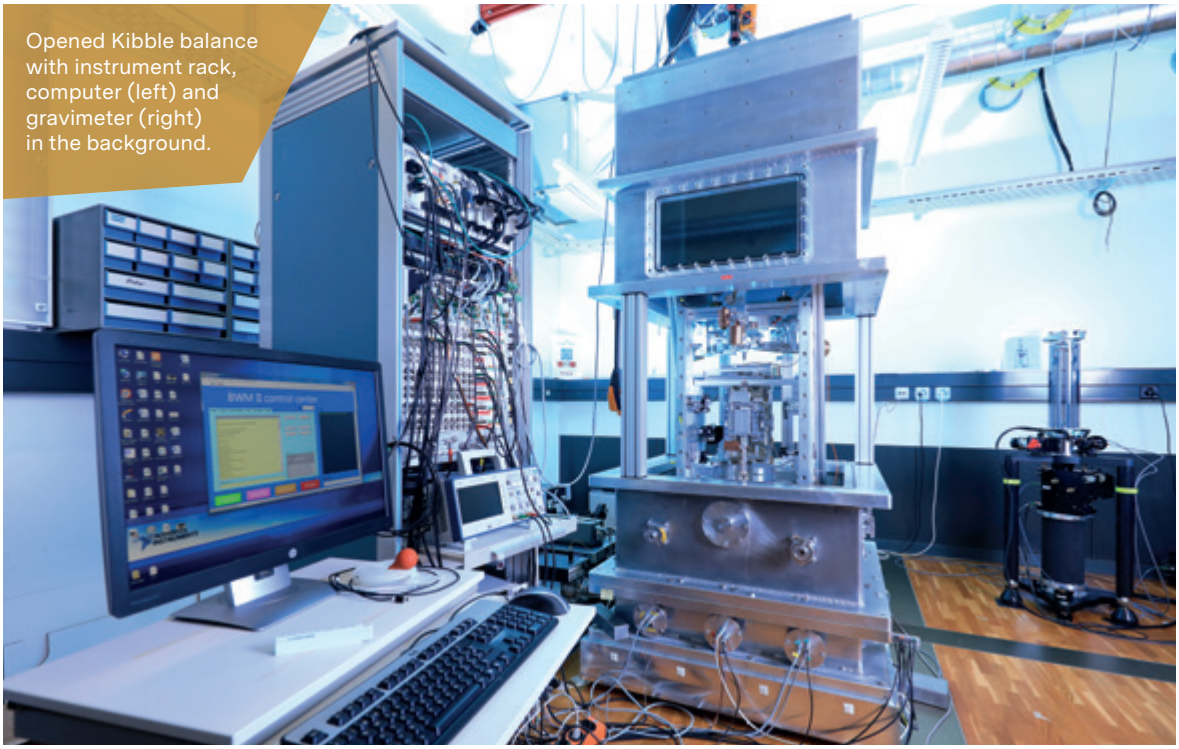
principles, especially for introducing the future redefinition of the SI unit second. It is based on optical clocks, meaning that the comparison of frequencies via fibre-optic networks will be essential.

Kibble balance

Until recently, the unit kilogram was defined by the international prototype of the kilogram. This is a cylinder made of a platinum-iridium alloy with a diameter and height of 39 mm. This artefact was stored carefully in a vault at the International Bureau of Weights and Measures in Paris. Metrology institutes around the world each received copies of this cylinder, including METAS, which has two of these copies of the prototype kilogram.

Since the end of the 1980s, metrologists have made a considerable effort to link the unit of mass to a physical constant, similar to the definition of the metre in relation to the speed of light *c*, for example. In 2017, a consistent link was established between the unit of mass and the Planck constant *h*, which led to a redefinition of the unit of mass in 2019. Throughout all these years, METAS contributed to these international endeavours by developing a Kibble balance. This type of balance makes it possible to determine the mass of an object in the local gravitational field very precisely. In order to achieve this, both the current and the voltage required to hold the system in equilibrium are measured.

After a lengthy development phase and a systematic evaluation of potential sources of error, two measurement campaigns could finally be conducted. In each, a test mass of 1 kg of stainless steel was measured and the difference between the consensus value and the mass measured using the Kibble balance was calculated. Each campaign lasted almost 14 days or over 300 hours of continuous measurement – with the result that the kilogram can be determined precisely up to 8 decimal places using the Kibble balance. This time-consuming experiment could be realised thanks to close cooperation with EPFL and other research institutes, as well as the European Organization for Nuclear Research (CERN) and Mettler Toledo.



Opened Kibble balance with instrument rack, computer (left) and gravimeter (right) in the background.

Industry

New technologies present metrological challenges for METAS

Due to the ongoing development of new production methods and materials in industry, new measuring procedures and international standards also need to be constantly developed. METAS supports these efforts by participating in international research projects.

The appearance of products and brands is a key factor in consumers' decision to purchase. Industry is therefore developing increasingly complex materials to generate visually appealing effects such as iridescence or sparkle, or to fulfil a specific function such as retroreflection. Traditional colour measurements are not suitable for recording these kinds of appearance characteristics. Instead, so-called bidirectional reflectance measurements are increasingly being used.

Measurable definition of the appearance of surfaces

The "BxDiff" project completed in October 2022 addressed the measurable, quantitative assessment of the visual appearance of a product. The project was realised as part of the European Metrology Programme for Innovation and Research (EMPIR).

The appearance of products not only depends on their material, colour, shape and lighting, but also on the distance from which they are viewed and the size of the object. The optical characteristics of materials must therefore be measured at different scales. Due to this, researchers on the "BxDiff" project also investigated measurements of small surfaces with dimensions of less than one millimetre.

The results are intended for all industrial sectors where optical appearance is particularly important to manufacturers and consumers. These include pigment manufacture, the watchmaking, automotive, paper, 3D printing and cosmetics industries, the manufacture of optical measuring instruments, as well as standardisation bodies.

Optimising 3D printing with metal using X-ray CT

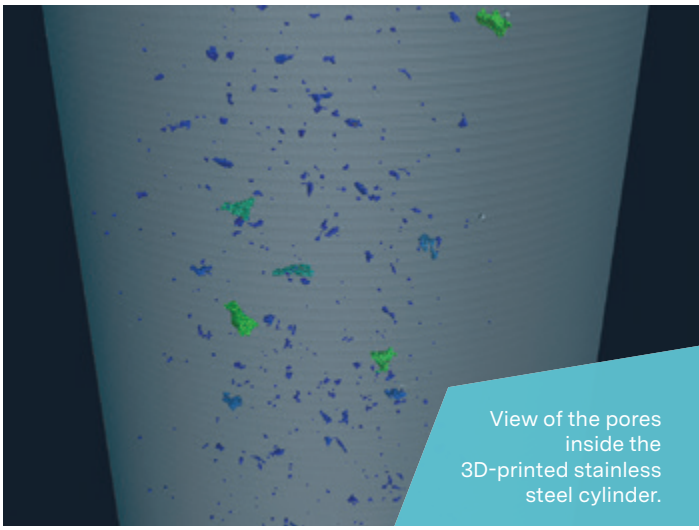
Compared with conventional methods such as milling, additive manufacturing techniques (3D printing) open up new possibilities for industrial production processes. This particularly applies when manufacturing small batches or for complex geometries with internal structures that may even be unfeasible using conventional methods. While the 3D printing of plastics is largely established, printing with metals is still an active field of research. The procedure

consists of locally melting metallic powder grains using a laser or an electron beam to print the part layer by layer.

Measuring the surface is not enough to assess the quality of a printed metal part because, for example, pores or a lack of fusion between grains in the interior may weaken its mechanical strength. Instead the object needs to be "seen through" and captured fully in three dimensions without destroying it. Computed tomography (CT) with X-rays can be used for this purpose.

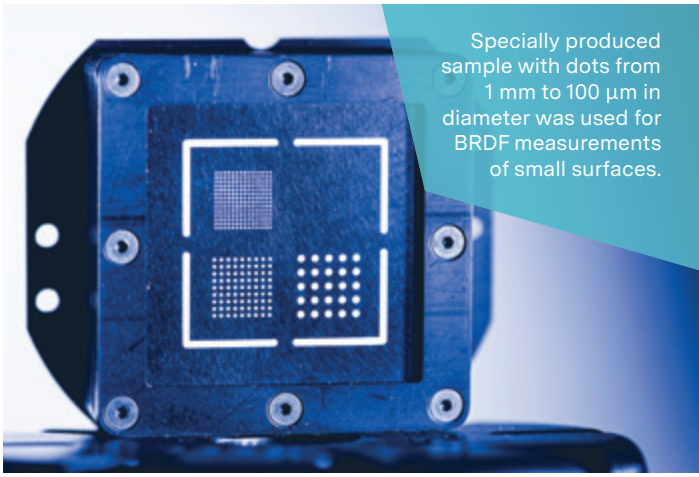
METAS has a CT machine that is able to capture objects in three dimensions with a total of 64 billion pixels. It reaches a spatial resolution of up to 1 µm and is therefore one of the most precise CT machines for industrial applications in the world. With this machine, METAS is participating in a research project supported by the EU funding programme Horizon 2020 involving partnerships from European academia and industry. In this project, METAS's CT machine is used for the quality control of printed prototypes, thereby making it possible to optimise the parameters of 3D printing processes.

View of the surface of a 3D-printed stainless steel cylinder with a diameter of 6 mm scanned using the METAS CT machine.

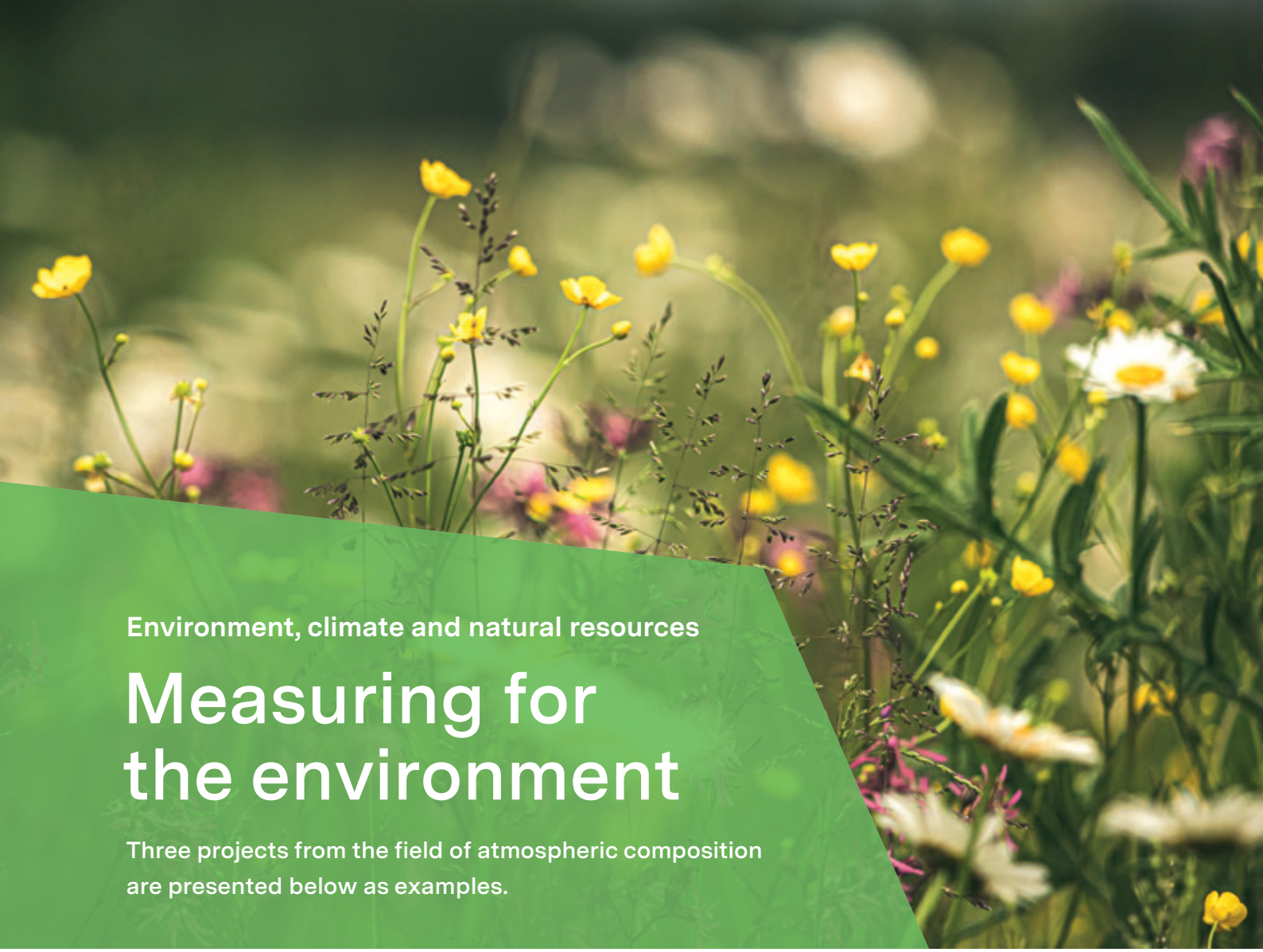


View of the pores inside the 3D-printed stainless steel cylinder.

Artificial leather sample used for the BRDF (bidirectional reflectance distribution function) measurements.



Specially produced sample with dots from 1 mm to 100 µm in diameter was used for BRDF measurements of small surfaces.



Environment, climate and natural resources

Measuring for the environment

Three projects from the field of atmospheric composition are presented below as examples.

According to information from the World Health Organization, 91% of people live in a region where air pollution limits are not complied with. Accurate monitoring of air quality is therefore crucial in order to implement measures to reduce emissions.

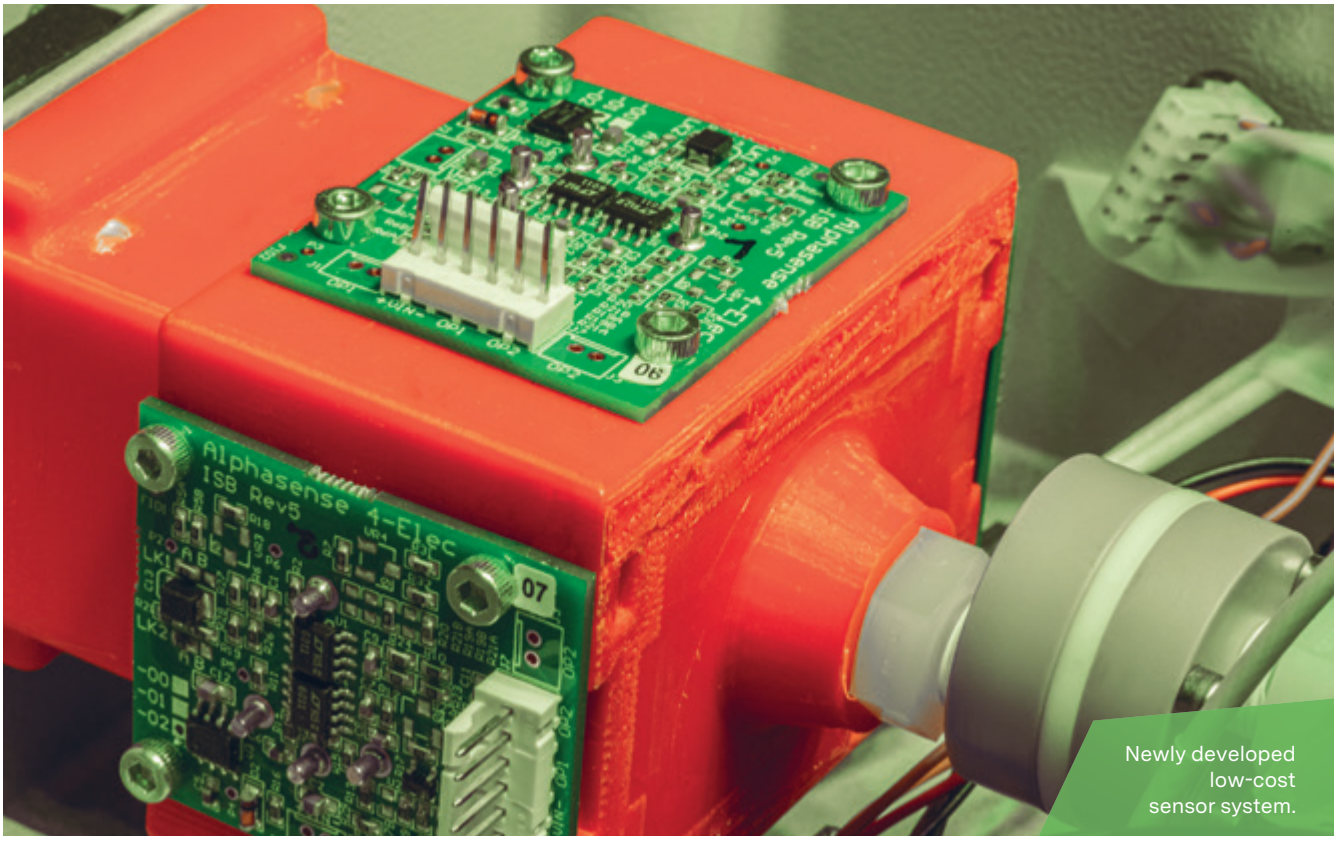
Air pollution control measurements with low-cost sensors

As part of an Innosuisse project, METAS collaborated with the company LNI Swissgas in Versoix and the organisation *Service de l'air, du bruit et des rayonnements non ionisants (SABRA)* in Geneva to develop a new, low-cost sensor system for measuring air quality. It measures the six pollutants carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), ozone (O_3) and particulate matter. To improve data quality, a suitable calibration process taking into account potential cross-sensitivities and enabling an adequate uncertainty estimation is required. For this purpose, METAS has developed an automaton that can be used for gaseous compounds to calibrate up to 17 devices simultaneously. The setup produces homogeneous gas mixtures made up of CO, NO, NO_2 and O_3 in the range of parts per billion (nmol/mol). These gas mixtures are traceable to the International System of Units (SI) and can therefore be compared worldwide.

Premature mortality due to air pollution

References for halogenated volatile organic substances

A large number of halogenated volatile organic substances can be found in the atmosphere. Chlorofluorocarbons (CFCs), which are now prohibited, and their successor products were used as coolants in refrigerators, among other applications. These substances make a significant contribution to climate change, which is why they must be measured accurately and comparably in the atmosphere around the world. There are no SI-traceable reference gases for most of these substances. Measure-



Newly developed low-cost sensor system.

ments of such substances are therefore difficult to compare because they are not based on internationally recognised standards. METAS has produced SI-traceable reference gases for 10 halogenated substances. These newly developed reference gases make it possible to compare measurements regardless of the method and location. In order to perform calibrations on site at the measuring stations, the reference gas must be transported to these stations. METAS has found a solution to this problem too: the reference gas is filled into stainless steel cylinders using a specially developed cryo-filling system and can thus be transported to the measuring stations.

Better measurements for pollen forecasting

Pollen concentration is measured routinely, particularly in industrialised countries. The monitoring networks currently rely almost exclusively on manual instruments developed in the 1950s. Over the past few years, several automatic pollen measuring devices have come onto the market which enable observations in real time, or almost real time. Together with MeteoSwiss and other European research institutes, METAS has calibrated three of these real-time pollen monitors against the primary standard for particle number concentration. Calibrations like these will help to make pollen monitoring even more accurate and reliable in future.


A stainless steel cylinder in liquid nitrogen is filled with a reference gas using the cryo-filling system.

Commitment to international organisations

METAS enjoys excellent links to international organisations and participates actively in their important committees. METAS and its employees are respected around the world as competent and reliable partners.

International cooperation is essential in the field of metrology. Only such cooperation made it possible to replace the multitude of coexisting regional units of measurement and unit systems with the International System of Units (SI) now valid worldwide. Internationally harmonised requirements for measuring instruments and measuring methods make trade in measuring instruments possible in the first place. Accordingly, international cooperation is of particular importance to METAS, Switzerland's national metrology institute.

Unit prefixes

The International System of Units (SI) also defines unit prefixes such as micro, nano, kilo or mega. Since quantities of data are growing larger and larger, and smaller and smaller dimensions are being examined, the SI prefix symbols gained four new additions in November 2022. For example, the mass of the earth is equal to 6 ronnagrams:

ronna (10^{27})
1 000 000 000 000 000 000 000 000 000
quetta (10^{30})
1 000 000 000 000 000 000 000 000 000 000

ronto (10^{-27})
0,000 000 000 000 000 000 000 000 001
quecto (10^{-30})
0,000 000 000 000 000 000 000 000 000 001

International cooperation principally takes place within the framework of the European Association of National Metrology Institutes (EURAMET). The European Cooperation in Legal Metrology (WELMEC) also plays a key role.

Represented in the Metre Convention since 1875

From a global perspective, cooperation with the *Bureau international des poids et mesures* (BIPM) in Paris, the office and research centre for the organisation of the 1875 Metre Convention, is particularly significant. The organisation's highest decision-making body is the *Conférence générale des poids et mesures* (CGPM), held every four years, at which all member states of the Metre Convention are represented. The 27th CGPM took place from 15 to 18 November 2022 in Versailles, where METAS represented Switzerland. In addition to key matters relating to the organisation of the Metre Convention, the attendees and Dr Philippe Richard, Director of METAS, addressed topics such as new unit prefixes for the International System of Units (SI) and the leap second.

CIML: next president to come from Switzerland

METAS also represents Switzerland in the *Organisation internationale de métrologie légale* (OIML). The OIML strives to harmonise legal metrology in the interests of global trade and consumer protection. The organisation makes its decisions annually within the framework of the *Comité international de métrologie légale* (CIML). The 57th meeting was held in

Some of the international organisations and associations

BIPM
Bureau international des poids et mesures

CGPM
Conférence générale des poids et mesures

CIPM
Comité international des poids et mesures

OIML
Organisation internationale de métrologie légale

CEN/CENELEC
Comité européen de normalisation en électrotechnique

CIE
Commission internationale de l'éclairage

EMETAS
European Metrological Type Approval Service

EURACHEM
A Focus for Analytical Chemistry in Europe

EURAMET
European Association of National Metrology Institutes

IEC
International Electrotechnical Commission

ISO
International Organization for Standardization

NoBoMet
Notified Bodies in Metrology

WELMEC
European Cooperation in Legal Metrology

October 2022, where Dr Bobjoseph Mathew, Deputy Director of METAS, was elected as the 10th CIML President for six years. He will take office at the 58th CIML meeting in autumn 2023.

Trustworthy energy measurement in electric vehicle charging stations

A specific example of the importance of international cooperation can currently be found with regard to electric vehicle charging stations. Anyone who drives an electric car relies on the fact that the energy measured at the charging station corresponds to the energy actually received. Energy measurement at charging stations for short-term customers in Switzerland is not yet regulated under metrology law. To ensure that the same charging stations as in our neighbouring countries can be used in Switzerland and that the same level of consumer protection is achieved, METAS has established an international network. It is co-ordinating EURAMET TCEM project 1539 "LegalEVcharge: Practical legal metrology framework for electric vehicle charging stations" and plays an active role in various other committees. METAS is committed to ensuring that maintenance work on electric charging stations which has no impact on measurement, such as cable replacement or electrical safety testing, does not entail any reverification procedures.

Abolition of the leap second

Since 1972, 27 leap seconds have been added to universal time to prevent our universal time as defined by atomic clocks from running ahead of astronomical time. Because adding leap seconds is very problematic in technical terms, this practice is set to end from 2035 – this was decided by the *Conférence générale des poids et mesures* (CGPM) in November 2022.

European metrology networks

European metrology networks implement the vision of the world-leading metrology capacity of EURAMET and its members. Together they meet the rapidly progressing needs of end users with high-quality scientific research and an efficient and integrated infrastructure. This cooperation is crucial for METAS and Switzerland, which is why METAS participates actively in seven out of a current total of eleven metrology networks. In 2022, it joined the newly established Environmental Monitoring and Safe and Sustainable Food networks.

Social and environmental responsibility

The way in which METAS fulfils its social and environmental responsibility is critical to its long-term success. In this context, it is important to foster a good and inclusive working environment and to take measures to reduce energy consumption.

The Executive Board considers it a priority to ensure that the working environment at METAS is respectful, as well as motivating and challenging.

Diversity is a top priority

METAS values diversity, interdisciplinarity and a constructive and transparent manner when dealing with others. In this regard, managers are particularly required to promote and embody the "METAS culture", boost employees' personal skills and help them to participate in internal and external seminars and training courses.

METAS implements the principle of equal pay between men and women in accordance with the Swiss Federal Constitution. In 2019, it signed the charter for equal pay in the public sector. By doing so, METAS has committed to implementing equal pay as far as it is able. In 2022, there was an equal pay audit with a pay analysis, which revealed that equal pay is guaranteed throughout the institute.

When recruiting and appointing new employees, METAS pays attention to ensuring diversity in areas such as gender, nationality, language and disability. Achieving adequate representation of the national languages within METAS is also a key concern.

METAS condemns all forms of sexual harassment, bullying and discrimination at work. It sees doing everything it can to provide its employees with appropriate protection as its duty. For example, the right to the protection of personal integrity in the workplace and to be able to consult internal and external specialists as points of contact regarding confidential and discreet matters is ensured as a matter of course.

Climate-neutral energy

In order to address environmental and climate protection, METAS participates voluntarily in the Resource and Environmental Management of the Federal Administration (RUMBA), focusing on the field of buildings (electricity, heat, water and waste) and on paper consumption and business travel. We met our targets set for 2021 with regard to reducing greenhouse gas emissions. Nevertheless, greenhouse gas emissions rose by 12 % to 585 tonnes.

Around 63 % of these emissions were due to increased heat consumption (in kWh) in the cold winter of 2021 and almost a third were due to business travel. METAS is committed to ensuring that international events are held alternately as videoconferences. If business trips are still necessary, they should be made with as few emissions as possible. As a result, greenhouse gas emissions caused by business travel by car and plane in 2021 were reduced by 8 tonnes compared to 2020. This shows that the measures introduced in 2021 to reduce emissions have had a successful start. Since 2019, greenhouse gas emissions have been offset by emission reduction certificates. Thanks to this, METAS is already climate-neutral. METAS still aims to reduce greenhouse gas emissions by a third, based on 2019 levels, by 2030.

In the past year, METAS put four electric charging stations for electric company vehicles into operation. In an initial phase, they were also used as test charging stations. Following the purchase of five electric company vehicles towards the end of last year, they were switched to normal operation.

Five new electric vehicles.

Financial information

METAS closed the 2022 financial year with a profit of CHF 1.2 million. Expenses amounted to CHF 51.9 million and revenues (including payments) totalled CHF 53.1 million.

Balance sheet	31.12.2022 in CHF 1000	31.12.2021 in CHF 1000
Cash and cash equivalents	28 136	27 928
Trade receivables	3 897	3 243
Receivables from research projects	2 130	2 187
Other receivables	257	65
Inventories	49	0
Prepaid expenses and accrued income	1 800	1 289
Current assets	**36 269**	**34 712**
Property, plant and equipment	19 445	20 324
Intangible assets	3 259	3 425
Non-current assets	**22 704**	**23 749**
Total assets	**58 973**	**58 461**
Trade payables	807	654
Liabilities to research projects	2 197	2 765
Other liabilities	939	633
Accrued expenses and deferred income	2 081	2 255
Current provisions	1 333	1 929 [1]
Short-term liabilities	**7 357**	**8 236**
Provision for pension fund liabilities	9 293	24 913
Provisions for loyalty bonuses	1 463	1 718
Long-term liabilities	**10 756**	**26 631**
Accumulated loss	–8 380	–9 330 [1]
Accumulated actuarial losses/gains	44 656	28 561
Reserves for non-current assets	3 413	3 413
Profit	1 171	950 [1]
Equity	**40 860**	**23 594**
Total liabilities	**58 973**	**58 461**

[1] The 2021 figures were adjusted due to a restatement, see notes on the restatement in the detailed annual accounts.

Profit and loss account

	2022 1.1.2022–31.12.2022 in CHF 1000	2021 1.1.2021–31.12.2021 in CHF 1000
Fees	8 983	8 829 [1]
Payments from the Federal Government	24 517	24 399
Federal Government payment with directly attributable return service	6 523	6 558
Revenue from external funding (excluding research)	10 502	9 729
External funding for research	1 882	2 153
Other revenue	135	274
Gross revenue	**52 542**	**51 942**
Reduction in revenue	–30	–5
Own work	527	718
Net revenue	**53 039**	**52 655**
Profit from sale of fixed assets	**8**	**8**
Expenditure on materials and third-party services	**–368**	**–269**
Personnel expenses	–35 676	–36 188
Room expenses	–6 780	–6 776
IT expenses	–1 854	–1 549
Other operating expenses	–3 029	–3 007
Depreciation	–3 905	–3 706
Operating expenses	**–51 244**	**–51 226**
Financial revenue	8	6
Financial expenses	–132	–125
Financial result	**–124**	**–119**
Tax expenses	**–140**	**–99**
Profit	**1 171**	**950** [1]

In the reporting year, METAS was able to finance 55.0 % of its activities itself (previous year: 54.7 % after restatement). Fees, payments for taking on other tasks and external funding contributed to this self-financing.
The auditors confirmed without reservation that the accounts were in proper order.

METAS's financial reporting is carried out in accordance with the International Public Sector Accounting Standards (IPSAS).

METAS publications and lectures

Research and development activities are also reflected in the publications and presentations that METAS researchers have produced or given.

In the reporting year, METAS staff once again presented the results of their research and development work at symposia, conferences and in scientific publications. They worked in professional organisations and committees at national and international level, where they contributed their expertise and experience. They communicated information about metrology to a wide audience outside the immediate professional circles of the sector and were involved in courses for students at universities. In the past year, most of the presentations, lectures and meetings once again had to be held online.

The following list contains an overview of the most important publications published and presentations given by METAS employees. The names of the METAS employees among the authors are highlighted in bold.

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Edition No. 860532198