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Federal Institute of Metrology METAS

Swiss Confederation



METAS in 2021



Cover picture: In September 2021, METAS commissioned a biology laboratory for the analysis of nucleic acids (see page 16).

Legal notice

This report provides an overview of the activities of METAS in the 2021 reporting year. Further information can be found in the METAS annual report, the annual report on the implementation of the Metrology Act (both published on www.metas.ch), the management salary report (published on www.epa.admin.ch) and the short report of the Federal Council on the fulfilment of the strategic objectives of the independent units of the Federal Government (published on www.efv.admin.ch).

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Pages 26 and 27 of this report contain information from the annual financial statements of METAS as at 31 December 2021. The 2021 annual financial statements of METAS have been published together with the auditor's report at www.metas.ch.

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Changes in the Institute Council



METAS has been a federal institute since 1 January 2013. The Institute Council of METAS has been in existence since 2012, meaning it was able to participate in the preparatory work for the establishment of the Institute and the commencement of operations. Right from the start, I was joined by Thierry Courvoisier and Tony Kaiser. They have now resigned from the Institute Council, effective from the end of the reporting year.

Both actively supported the preparations for the institute going into operation. Once METAS began operating as an institute, they also played a role in defining the strategic direction and, in particular, in shaping METAS's research and development programme. Dr Tony Kaiser has contributed his extensive experience from his work in various positions in research and development management in the

world of industry. At the same time, Prof. Dr Thierry Courvoisier brought the world of science as well as the realm of science organisations and science management to the Institute Council. I would like to express my sincere thanks to Tony Kaiser and Thierry Courvoisier for their great commitment to METAS and the pleasant working relationship we have enjoyed over the years.

The Institute Council continues to fulfil its mandate of defining the strategic direction of METAS together with the Executive Board and, in particular, working on the orientation of research and development at METAS.

Dr Matthias Kaiserswerth
President of the Institute Council



The Institute Council fulfils its mandate of defining the strategic direction of METAS together with the Executive Board.



Implementing the METAS 2025 vision

The coronavirus pandemic once again impacted the operations of METAS in the 2021 financial year. As in the previous year, it was necessary to constantly adjust to the current pandemic situation and to take and implement the measures required to protect the health of employees and third parties. Despite all the changes and adjustments, operations at METAS were able to be maintained and its services provided. This was only possible thanks to the tremendous commitment of the METAS employees, who adapted quickly and flexibly and carried out their work even under conditions they were not used to.

The work of the Executive Board in 2020 and 2021 was shaped not only by the coronavirus pandemic, but also by the METAS 2025 vision. This was drawn up in 2020 and approved by the Institute Council in November. The METAS 2025 vision provides the framework for a programme of change and defines the direction in which METAS intends to develop. Like all national metrology institutes, METAS will

be faced with major challenges in the coming years. For example, digitalisation will change metrological services. In addition to the classical physical fields, chemical and biological references are becoming increasingly important. It is also important to take account of modern forms of customer contact as well as new organisational and working forms. In the reporting year, the aim was to begin implementing the METAS 2025 vision. Among other things, two new divisions have been created: Digital Transformation, and Customer Service and Communication. The management teams of the divisions have been staffed with proven specialists. They started their work in the year under review and will continue to work in these divisions with their teams and in close cooperation with the other METAS units over the next few years.

Dr Philippe Richard
Director



The METAS staff adapted quickly and flexibly and carried out their work even under conditions they were not used to.



Measuring for business and society: the tasks of METAS

Wabern is where Switzerland's most accurate measurements are taken. This is where the Federal Institute of Metrology METAS is located – Switzerland's metrological reference centre.

METAS is Switzerland's national metrology institute. It is the federal competence centre for all matters relating to measuring, measuring equipment and measuring procedures. With its research and development activities and services, it creates the conditions for measuring in Switzerland with the accuracy required for the interests of business, research, administration and society.

Binding reference measurements

METAS realises Switzerland's reference standards, ensures that they are recognised internationally and distributed with the necessary accuracy. This is how the institute provides the basic metrological infrastructure for business and society. This is important wherever measurements are being taken.

METAS oversees the market launch process, use and control of measuring instruments in trade, transport, public safety, healthcare and environmental protection. It ensures that the measurements required for the protection and safety of people and the environment can be taken correctly and in accordance with regulations.



Progress requires precision

Things can only be reliably manufactured and monitored if they can be accurately measured. Science and technology are therefore dependent on constantly evolving metrological principles and procedures. Measurement and control methods used by major sectors of the Swiss economy, such as micro-technology and medical technology, require measurement methods with an accuracy of one millionth of a millimetre.

Metrology

Metrology is the science and technology of making measurements (from the Greek word *metron*, meaning “measure”). *Metrology* is frequently confused with *meteorology*. However, these two fields are clearly distinct. *Meteorology* is the study of weather phenomena (from the Greek word *meteoros*, meaning “raised from the ground”).



METAS keeps track of scientific and technical developments in order to stay up to date at all times. It conducts research and development to identify and anticipate market needs for new or more accurate measuring stations and services. It regularly reviews its services in order to adapt them to the needs of the market.



The place where Switzerland takes its most accurate measurements:
at METAS in Wabern.

Managing METAS: Institute Council and Executive Board

At the head of METAS is the Institute Council. It is responsible for managing the corporate side of the institute. Operational management is the responsibility of the Executive Board.

In accordance with the statutory requirements, the Institute Council is made up of five to seven expert members. In the reporting year, it consisted of seven members: Dr Matthias Kaiserswerth (President), Dr Ursula Widmer (Vice President), Prof. Dr Thierry Courvoisier, Dr Tony Kaiser, Prof. Dr Sonia Isabelle Seneviratne, Dr Alessandra Curioni-Fontecedro, Dr René Lenggenhager.

Two of the members resigned at the end of 2021: Prof. Dr Thierry Courvoisier, Dr Tony Kaiser.

The tasks of the Institute Council are defined in the Institute Act. It applies to the Federal Council for payments for the services to be provided by the Federal Government and approves the research and development programme. It supervises the Executive Board and issues the personnel regulations. The members of the Institute Council have extensive management experience, both in the worlds of academia and business, and have many years of broad expertise in research and development in the natural sciences and technology.

The METAS 2025 vision

One of the Institute Council's most important tasks is to define the strategic direction of METAS together with the Executive Board. In doing so, it follows the guidelines of the Federal Council, which are set out in the strategic objectives for METAS. The METAS 2025 vision, which was approved by the Institute Council in November 2020, forms the guiding principle for the further development of METAS in the coming years. This programme of change represents METAS's response to the challenges associated with expected developments in a wide range of important areas: in the field of metrology, the expectations of stakeholders, digitalisation and other areas of society.



Members of the Institute Council in 2021 (from left to right): Dr Matthias Kaiserswerth (President), Prof. Dr Thierry J.-L. Courvoisier, Dr Tony Kaiser; Dr Ursula Widmer, Prof. Dr Sonia I. Seneviratne, Dr Alessandra Curioni-Fontecedro, Dr René Lenggenhager.

Operational management

The Executive Board is responsible for the operational management of METAS. It represents METAS to the outside world. It consists of four members: Dr Philippe Richard (Director), Dr Gregor Dudle (Deputy Director), and the Vice Directors Dr Bob-joseph Mathew and Dr Hanspeter Andres.

An important focal point of the Executive Board's activities this year was the implementation of measures to realise the METAS 2025 vision. In addition, defining and implementing measures that were necessary due to the coronavirus pandemic continued to dominate day-to-day operations.



The METAS Executive Board (from left to right):
Dr Philippe Richard (Director), Dr Gregor Dudle,
Dr Bob-joseph Mathew, Dr Hanspeter Andres.

Measurement projects: research and development at METAS

METAS carries out much of its research work as part of European metrology research programmes.

International cooperation is deeply rooted in metrology. The standardisation of the definition of length and mass in the 19th century and later of the other relevant quantities in the International System of Units (SI) laid the foundation for global standardisation. In Europe, international cooperation in metrology in recent years has largely taken place within the framework of the *European Metrology Programme for Innovation and Research* (EMPIR). EMPIR was developed by EURAMET (the European Association of National Metrology Institutes) and the European Commission to better coordinate the research carried out by national metrology institutes. The programme funded metrological research projects between 2014 and 2020. The most recent projects under the EMPIR programme were approved in 2020. In the reporting year, METAS participated in 30 European projects across a wide range of topics.

Energy from hydrogen

Two of these projects are concerned with hydrogen as an energy carrier, especially for use in mobility. There are many challenges for metrology in this area. For example, it must be possible to guarantee metrological traceability along the entire hydrogen distribution chain. The aim is to investigate and clarify open questions regarding measurement under high pressure, simulation and measurement of liquid hydrogen. However, it must also be possible to determine the mass of hydrogen that is absorbed when filling fuel cells. In addition, reference materials and reliable methods for determining the purity of the hydrogen need to be developed. This is necessary not least to ensure that hydrogen refuelling complies with legal requirements.

New metrology research programme

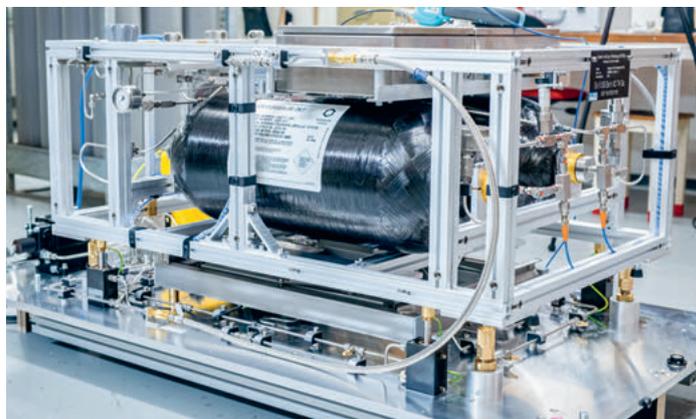
Topics such as contributions to the hydrogen economy will also be pursued within the framework of a new European metrology research programme. Within *Horizon Europe* – the framework programme for research funding in Europe launched in 2021 – metrology was once again awarded a dedicated research programme: The *European Partnership on Metrology* (EPM) was officially launched on 1 December 2021. Over its seven-year implementation period, the EPM has a budget of more than EUR 700 million at its disposal. The research programme will also address sociopolitical challenges





such as the Green Deal, health and digitalisation. In the first phase of the EPM, another project in the field of hydrogen was approved. Here, too, METAS brings its expertise in the field of flow measurement to the table.

All these research projects are intended to make it possible to contribute to sustainable mobility through the use of hydrogen.



Measuring device for verifying hydrogen filling stations.

Measuring in the service of product development: cooperation projects with industry

METAS is funded by Innosuisse as a research partner. This allows companies to use the research and development expertise of METAS for their innovations and carry out applied research projects together with METAS.

Everyone is talking about the energy transition. In order to secure the supply of electricity in Switzerland even after phasing out nuclear energy and the discontinued use of fossil fuels, photovoltaic and wind power are to be used increasingly to generate electricity in addition to hydroelectric power. This makes electricity production more volatile on the one hand, but also more locally distributed. This poses challenges for the power grid.

Information about network parameters

The challenges of decentralised electricity production can only be mastered with reliable information on the parameters of the power grid. Condis, based in Rossens, is an innovative manufacturer of such non-conventional measuring instruments, which are used in the construction of modern electrical substations. These devices, called “Low Power Instrument Transformers” (LPIT), must of course also provide reliable measurement values, be calibrated, and the measurement uncertainty needs to be able to be correctly estimated. It is precisely in this area that METAS has the technical and scientific knowledge and relevant experience. There is already a laboratory facility at METAS which allows these LPIT devices to be calibrated by specialist staff using bulky measuring devices.

Inspection and calibration in the network

The aim of the “Mobile Instrument Transformer Calibration System” project supported by Innosuisse is to develop a transportable system that enables the inspection and calibration of the LPIT measuring devices installed in the network. A compact device like this could be used in manufacturing processes as well as for the approval of components, thus optimising both quality and processes.



The reference system is being designed in cooperation with Condis, while the software component (data extraction and processing) has been taken over by METAS. METAS has been able to build up the necessary expertise in dealing with digitised data in recent years. Now half way through its scheduled running time, the project is well under way, even despite delays due to the coronavirus pandemic. In addition to the existing hardware prototypes, an error estimation module must also be added to the analysis software.



This collaboration will enable METAS to share its scientific and technical expertise with its partner in industry. In turn, the latter will have a product with a unique selling point that not only serves the economic development of the company, but also makes it possible to contribute to successfully mastering the energy revolution.



Calibration of measuring instruments to determine network parameters.

Metrology for business: calibrations and reference materials

With the services it offers, METAS helps numerous companies from various economic sectors to take measurements correctly and reliably. This enables them to meet the quality requirements demanded of their products. This also applies to certified reference materials.

METAS provides numerous calibration, measuring and testing services for industry and administration alike. For example, around 4,800 calibration certificates were issued in 2021. The most important customer segments are the mechanical engineering, electrical, metalworking and watchmaking industries along with medicine and communication technology.

The traditional services provided by a national metrology institute, such as calibration, are important for the economy and will continue to be offered. However, services are also increasingly playing a role in other areas. For example, certified reference materials are important for traceable chemical analyses. The traceability of analytical results to the SI needs to be ensured by reference measurement methods and traceable reference materials.

Food safety

Certified reference materials are used, among other things, in food analysis. These analyses are carried out in the interests of food safety. Foods contaminated by bacteria, viruses or chemical substances can lead to diseases ranging from diarrhoea to cancer. These kinds of substances may enter or form in food during the manufacturing process, or during distribution and sale. To protect consumers, the content of these substances in foodstuffs is regulated by law and food is checked for them. In order to be able to carry out the investigations required for these checks, comparable measuring methods are required. This is ensured by the national reference laboratories.

In Switzerland, the Federal Food Safety and Veterinary Office (FSVO) is responsible for food safety. It lays down regulations for the national reference laboratories, among others. Based on its expertise, METAS has been appointed by the FSVO as a reference laboratory for process contaminants in foodstuffs, and also as a reference laboratory for metals and nitrogen compounds in foodstuffs.





Certified reference materials

Certified reference materials are essential in ensuring that food manufacturers can trace the measurement results in their analyses back to recognised reference values and thus guarantee the accuracy and reliability of the measurements they take. METAS supports the need for reference measurement methods and traceable reference materials. It will offer its first certified reference materials on chemical impurities in whey protein. Whey protein is widely used in the food industry, including in the manufacture of baby food. It is also an important component of sports nutrition products.



Reference materials for food safety – investigating whey protein.

Measuring in healthcare and health protection: the new nucleic acid analysis laboratory

In order to expand its measurement capabilities in the area of nucleic acid analysis, METAS has set up a biology laboratory, which went into operation in autumn 2021.

Measurements contribute to the protection of health in a wide variety of areas: from the determination of radon concentrations in basements, to measurements of air pollution and noise measurements. To highlight the importance of measurements for the area of health, World Metrology Day 2021 was dedicated to the topic of measuring for health.

Measurements in laboratory medicine

Measurements also play a vital role in medical treatment. This starts with simple measurements of body temperature or blood pressure and extends to laboratory blood tests and complex genetic analyses. Results from measurements or analyses are used for around 70 per cent of all treatments in medical practices, whether as the basis for a decision or to review the success of treatment. 132 million analyses are carried out every year in Swiss medical laboratories. The complexity of the 1,200 or so different laboratory analyses depends heavily on the analyte in question. While chemical parameters such as the concentration of ions in the blood are relatively easy to measure and compare, standardising measurements of genetic tests or proteins is more complex and makes it difficult to compare measurement results.

Traceable measuring in medicine

In laboratory medicine, traceable measurements – as are common in physics and some areas of chemistry – are also becoming increasingly important. METAS has expertise and extensive experience in the comparability, accuracy and traceability of measurements. Within the scope of its statutory mandate and in the interests of a high-quality Swiss healthcare system, METAS is also available as a point of contact for those involved in laboratory medicine.

In the field of laboratory medicine, METAS specialises in nucleic acid metrology. Analyses of nucleic acids account for around 8 per cent (and rising) of all analyses carried out, but are still not extensively standardised. Here, METAS works closely with other national metrology institutes as well as users and manufacturers of in vitro diagnostics with the aim of further improving the quality and comparability of laboratory medical examinations and reducing costs in this area. In order to lay the foundations for metrologically traceable measurements in the field of nucleic acid analysis and to be able to





offer services for this purpose, METAS has set up a biology laboratory, which went into operation in September 2021.

In its activities in the field of nucleic acid metrology, METAS does not act as an inspector or as a diagnostic provider. It aims to shape developments in this field over the long term and positions itself as a reliable contact partner and service provider for questions regarding the metrological traceability of nucleic acids.



The new biology laboratory for the investigation of nucleic acids.

Regulating measurements: legislation in the field of metrology

The ordinances in the field of metrology regulate the requirements for numerous categories of measuring instruments. The technical development of measuring instruments and altered circumstances in which they are used require constant adjustments to the legal basis.

Participation in the preparation of ordinances in the field of metrology is one of the statutory duties of METAS. In 2021, two amendments to ordinances specific to measuring instruments were adopted and several further amendments drafted, one of which concerns charging stations for electric vehicles. The Federal Department of Justice and Police (FDJP), which issues ordinances specific to measuring instruments, is responsible for the amendments.

Nanoparticles and sound measurement

Firstly, the FDJP Ordinance on Exhaust Gas Measurement Equipment for Internal Combustion Engines was amended. Since 15 April 2021, this measuring equipment must be marketed with proper approval and have undergone an initial verification; a national conformity procedure was previously envisaged. The amendment to the ordinance ensures that all measuring instruments for nanoparticles from combustion engines that are marketed in Switzerland are checked to ensure that they comply with Swiss requirements. This prevents measuring instruments from entering the market that meet foreign requirements but do not comply with Swiss regulations and then fail the first verification after one year.

Secondly, the FDJP Ordinance on Instruments for Sound Measurement has been brought up to date by updating the references (standards and ordinances).

Preparations for regulating electric charging stations

The electricity meters in charging stations for electric vehicles are currently not subject to the Metrology Act and the Measuring Instruments Ordinance. When the FDJP Ordinance on Measuring Equipment for Electrical Energy and Power was completely revised in 2015, there was a conscious decision to not regulate these electricity meters yet. At the time, technical issues related to the electrical charging stations were still unresolved, and charging for electric vehicles based on the energy





consumed was not yet common practice. When the ordinance was adopted, it was envisaged that electricity meters at electric charging stations would be included in the legislation sooner or later. In 2021, METAS carried out various tasks to prepare a future regulation. The planned amendment to the FDJP Ordinance on Measuring Equipment for Electrical Energy and Power should also include a transitional regulation that will allow previously installed electrical charging stations to continue to be used as far as possible. A stakeholder consultation is planned for 2022.



Electric charging stations: regulations for metrological requirements are being prepared.

Measurements across borders: international metrology organisations

METAS – and thus Switzerland – has an above-average presence in international metrology organisations. The commitment of METAS employees at an international level is significant.

International cooperation is essential in the field of metrology. Only through this was it possible to replace the multitude of coexisting units of measurement and unit systems which had regional validity with the SI system. Internationally harmonised requirements for measuring instruments and measuring methods make trade possible in the first place.

Cooperation in Europe...

Cooperation between the national metrology institutes in Europe takes place mainly within the framework of EURAMET, the European Association of National Metrology Institutes, which deals with scientific and industrial metrology. The organisation was instrumental in developing the metrology research and development programme EMPIR and the successor programme *European Partnership on Metrology* (EPM) (see page 10). METAS plays an active and creative role in EURAMET. The Deputy Director is a member of the Board of Directors and METAS provides the Chair of the *Electricity and Magnetism* Technical Committee.

... and worldwide

METAS is also prominently represented in global associations. One of the Vice Directors of METAS is one of the vice presidents of the *Comité international de métrologie légale* (CIML), the steering body of the *Organisation internationale de métrologie légale* (OIML).

The Director of METAS is a member of the *Comité international des poids et mesures* (CIPM), the supervisory body of the organisation of the international Metre Convention.

Since June 2019, the head of the optics laboratory has served as president of the *Commission Internationale de l'Éclairage* (CIE), the international body for standards in the field of lighting technology and illumination.





These and other engagements in international specialist organisations demonstrate the international esteem in which METAS and its employees are held as a competent and reliable partner.



Most meetings of technical committees or other meetings could not take place on site, but as videoconferences.

The METAS climate package

METAS makes sure that its facilities are operated in a way that is as resource-friendly as possible in order to contribute to environmental protection and climate protection. It also participates in the Federal Resource and Environmental Management System (RUMBA).

Part of METAS's mission is to ensure that the measurements required to protect the environment are taken correctly at all times and in accordance with the relevant statutory provisions. This is also enshrined in the Federal Council's strategic objectives for METAS.

Measuring principles for air quality

METAS provides reliable measurement principles in a wide range of areas relevant to environmental protection. For measurements to test and ensure air purity, for example, gaseous air pollutants or climate-relevant gases must be reliably and accurately measured over long time series. High-performance, reliable particle measuring devices are important for determining particulate pollution in the air. With its high-precision measuring instruments and measuring procedures, METAS ensures the traceability of measurement results from gas analysis or particle measurement to internationally agreed reference values and contributes to internationally recognised measurement scales.

Contributing to climate protection

However, METAS cannot content itself with providing the metrological principles and measuring methods required to ensure that measurements for environmental protection and climate protection can be carried out reliably and accurately. It also has to – and wants to – make sure that it can operate its facilities in a way that is as resource-conscious and climate-friendly as possible.

The operation of the air-conditioning systems poses a particular challenge. Well-functioning, monitored air conditioning is essential for the METAS laboratories. A defined reference temperature must be maintained at the measuring stations. For most metrological disciplines, this is 20 degrees Celsius. This requires high-performance air-conditioning technology that consumes a lot of energy. The aim here is to reduce energy consumption by means of optimisation measures while still providing the required performance.



In order to systematically and consistently address environmental and climate protection concerns, METAS has developed an environmental management system and integrated it into its management system. METAS, as a decentralised unit of the federal government, participates voluntarily in RUMBA. RUMBA, which provides systematic resource management, focuses on the building sector (consumption of electricity, heat, water and generation of waste) on the one hand, and on paper consumption and business travel on the other.

As important as international cooperation in metrology is, it is important to ensure that there is less travel overall. METAS is actively committed to



ensuring that meetings of international working groups do not necessarily take place on site in all cases. The aim is for future meetings to be held alternately as face-to-face events and online as videoconferences.

METAS has committed to reducing its greenhouse gas emissions by 32 per cent by 2030. The reduction relates to the level of emissions in 2019. The operational measures are part of RUMBA. Since 2019, greenhouse gas emissions have been offset by emission reduction certificates. Thanks to this offsetting, METAS is climate-neutral.



The laboratories at METAS rely on high-performance air-conditioning technology.

Measuring in focus: the organisation of METAS

METAS is divided into three divisions that perform the various metrological tasks. In order to be able to carry out their activities effectively and efficiently, they are supported by cross-departmental sectors.

Most METAS employees work in laboratories. They provide metrological services, perform verifications, carry out analyses, maintain measuring equipment or work on the research and development of new measuring possibilities.

Three divisions

The staff responsible for performing the metrological tasks are organised into the divisions of Physics, Chemistry and Legal Metrology. These three divisions carry out the core metrological activities. In order to be able to carry out their activities effectively and efficiently, they are supported by cross-departmental sectors.

Supporting cross-departmental sectors

Support is needed in many areas, from various technical fields and R&D, infrastructure and logistics and administrative activities to customer service and communication.

Organisation chart

Institute Council

Matthias Kaiserswerth

Executive Board

Philippe Richard*

Research and Development

Corporate services

- Corporate affairs
- Finances and Controlling
- Customer service and communication
- Human Resources and Organizational Development
- Central Secretariat

Technology and Operations

- Digital transformation
- Informatic
- Infrastructure and Logistics
- Technology

*Member of the Executive Board

METAS as a training place

METAS is strongly committed to vocational training and launching professional careers, which is reflected in its relatively high proportion of apprentices in relation to the total workforce (6.1 per cent). It offers six different apprenticeships in technical and scientific fields (chemical lab technician, electronics technician, computer scientist, ICT specialist, physics laboratory technician, mediamatics specialist). A one-year business management internship in the commercial field is also offered. In 2021, METAS continued to employ various successful apprenticeship graduates as young professionals for several months. All apprentices in the final year of their apprenticeship successfully completed their training in 2021. METAS also offers a range of university internships.

Measuring stations and metrological laboratories rely on precisely regulated and constantly monitored operating conditions. In particular, the temperature and humidity must be kept as constant as possible and measured continuously. Measuring equipment should also be as well protected as possible against vibrations and other disturbances. The proper and smooth operation of the building technology is crucial for the work in the METAS laboratories (see also page 22).

Start as of 1st of April 2022



Federal Institute of Metrology METAS

Physics

Gregor Dudle*

- Electricity
- Length, Optics and Time
- Mechanical Quantities and Ionising Radiation

Chemistry

Hanspeter Andres*

- Chemical and Biological Metrology
- Chemical Testing and Consulting

Legal Metrology

Bob Joseph Mathew*

- Surveillance and Metrological Supervision
- Verifications and Tests
- Law
- Monitoring networks
- Conformity Evaluation Body METAS-Cert

Focus on core activities: the organisation of METAS.

Support in technical matters is also key. On the one hand, the sector Technology provides this in many areas: from design to mechanical production and electronics to the programming of metrological processes and evaluations for specific measuring stations. On the other hand, the sectors Informatic and Digital Transformation ensure that the necessary digital infrastructure and equipment are available.

Administrative support of various types and at various levels is required to ensure that customer orders can be processed efficiently and development projects can be carried out successfully. This ranges from the concrete receipt of deliveries and dispatch of calibrated measuring instruments to purchasing, finance, secretarial services and management, through to customer service and communication.

Financial information

METAS closed the 2021 financial year with a profit of CHF 1.1 million. Expenses amounted to CHF 51.6 million and revenues (including payments) amounted to CHF 52.8 million.

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

Balance sheet

(in thousand CHF)	31.12.2021	31.12.2020
Assets		
Cash and cash equivalents	27 928	26 941
Trade receivables	3 243	2 466
Receivables from research projects	2 187	2 889
Other receivables	65	172
Prepaid expenses and accrued income	1 289	1 056
Current assets	34 712	33 524
Property, plant and equipment	20 324	19 778
Intangible assets	3 425	2 131
Non-current assets	23 749	21 909
Total assets	58 461	55 433
Liabilities and equity		
Trade payables	654	524
Liabilities to research projects	2 765	3 825
Other liabilities	633	1 123
Accrued expenses and deferred income	2 255	296
Current provisions	1 294	1 227
Short-term liabilities	7 601	6 995
Provision for pension fund liabilities	24 913	42 839
Provisions for loyalty bonuses	1 718	1 603
Long-term liabilities	26 631	44 442
Accumulated loss	-8 825	-11 313
Accumulated actuarial losses/gains	28 561	9 408
Reserves for non-current assets	3 413	3 413
Profit	1 080	2 488
Equity	24 229	3 996
Total liabilities	58 461	55 433

Profit and loss account

(in thousand CHF)	2021 1.1.2021–31.12.2021	2020 1.1.2020–31.12.2020
Net revenue	52 785	52 608
Profit from sale of fixed assets	8	0
Expenditure on materials and third-party services	–269	–331
Personnel expenses	–36 188	–34 853
Room expenses	–6 776	–6 821
IT expenses	–1 549	–1 482
Other operation expenses	–3 007	–2 891
Depreciation	–3 706	–3 641
Operating expenses	–51 226	–49 688
Financial revenue	6	57
Financial expenses	125	–12
Financial result	–119	–45
Tax expenses	–99	–146
Profit	1 080	2 488

In the reporting year, METAS was able to finance 54.9 per cent of its activities itself (previous year: 56.7 per cent). 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.

The detailed, IPSAS-compliant annual accounts can be downloaded from the METAS website or ordered from METAS.

Learning about measuring: METAS publications and lectures

Research and development activities are also reflected in the publications and lectures 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. This year, most of the presentations, lectures and meetings had to be held online.

An overview of the publications published by METAS employees and presentations given by them can be found at the end of this section. A series of specialist lectures was also given as part of events at METAS itself.

“METinfo” journal

In 2021, METAS published two issues of the metrology journal METinfo, whose articles are usually written by METAS employees. Several METinfo articles have been reproduced in specialist journals across various fields.

Insight into the laboratories

It was planned that METAS would once again be involved in the “Mädchen – Technik – Los!” (Girls – Tech – Let’s go!) programme held as part of National Future Day. As part of this programme, a group of girls are given an insight into the tasks and activities of some of the laboratories at METAS. This should have taken place at the beginning of November but, as in the previous year, the events on Future Day had to be cancelled due to the coronavirus pandemic.

Similarly, it was not possible to organise group visits in the year under review. Visits make it possible to illustrate and familiarise visitors with the tasks and activities of METAS. Visits and events will be held again at METAS as soon as reasonably possible taking the pandemic situation into account.

Publications and lectures

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

Publications

- Iida, K., Sakurai, H., **Auderset, K.**, **Vasilatou, K.**: *Using an inkjet aerosol generator to study particle bounce in optical particle counters*. *Aerosol Science and Technology* 55 (2021), 1165-1182.
- Ferrero, A., Perales, E., **Basic, N.** (...), **Blattner, P.**: *Preliminary measurement scales for sparkle and graininess*. *Optics Express* 29 (2021), Issue 5, 7589-7600.
- Bircher, B.**: *Computed tomography for dimensional metrology: Design considerations for high-resolution CT systems*. *Proceedings of the International School of Physics “Enrico Fermi” 206* (2021), 373-378.
- Bircher, B. A.**; **Meli, F.**; **Küng, A.**, **Thalmann, R.**: *METAS-CT: Metrological X-ray computed tomography at sub-micrometre precision*. *euspen’s 20th International Conference & Exhibition, Geneva, Switzerland*. 2021, 4pp.
- Bircher, B.**, **Wyss, S.**, **Gage, D.**, **Küng, A.**, **Meli, F.**, **Körner, C.**: *High-resolution X-ray computed tomography for additive manufacturing: Towards traceable porosity defect measurements using digital twins*. *euspen SIG Advancing Precision in Additive Manufacturing, St. Gallen*, 2021, 4pp.
- Bircher, B.**, **Neuhaus, S.**, **Küng, A.**, **Meli, F.**: *Measurement of temperature induced X-ray tube transmission target displacements for dimensional computed tomography*. *Precision Engineering* 72 (2021), 406-416.
- Ess, M.** (...), **Vasilatou, K.**: *Optical and morphological properties of soot particles generated by the mini-CAST 5201 BC generator*. *Aerosol Science and Technology* (2021), 21 pp.
- Ess, M.** (...), **Vasilatou, K.**: *Coated soot particles with tunable, well-controlled properties generated in the laboratory with a miniCAST BC and a micro smog chamber*. *Journal of Aerosol Science* 157 (2021), 105820, 15pp.
- Horender, S.**, **Tancev, G.**, **Auderset, K.**, **Vasilatou, K.**: *Traceable PM_{2.5} and PM₁₀ Calibration of Low-Cost Sensors with Ambient-like Aerosols Generated in the Laboratory*. *Applied Sciences* 11 (2021), 9014.
- Horender, S.**, **Auderset, K.** (...), **Vasilatou, K.**: *Facility for production of ambient-like model aerosols (PALMA) in the laboratory: application in the inter-comparison of automated PM monitors with the reference gravimetric method*. *Atmospheric Measurement Techniques* 14 (2021), 1225-1238.
- Husmann, D.**; **Bernier, L.** (...), **Morel, J.**: *SI-traceable frequency dissemination at 1572.06 nm in a stabilized fiber network with ring topology*. *Optics Express*, 29 (2021), Issue 16, 24592-24605.
- Sobanski, N. (...), **Iturrate, M.**, **Pascale, C.** et al.: *Advances in High-Precision NO₂ Measurement by Quantum Cascade Laser Absorption Spectroscopy*. *Applied Science* 11 (2021), no. 1222, 2076-3417.
- Ogrinc, N. (...), **Mallia, S.**, **Umbrecht, G.**, et al.: *Support for a European metrology network on food safety Food-MetNet*. *Measurement: Sensors*, 18 (2021), 100285.
- Seferi, Y.; Blair, S.M.; **Mester, C.**; Stewart, B.G.: *A Novel Arc Detection Method for DC Railway Systems*. *Energies* 14 (2021), 444, 21 p.

Mester, C.: Optimised calibration programmes for comparators for instrument transformers. In: Technisches Messen, 88 (2021), 122-131.

Mester, C.: Technologiegerechtes Kalibrierprogramm für moderne Messgeräte – Neue Möglichkeiten durch Kalibrierung tatsächlich nutzbar machen. In: Messunsicherheit 2019. Messunsicherheit praxisgerecht bestimmen. Düsseldorf 2021, VDI-Verlag, 75-86.

Weidinger, P. (...), **Mester, C.**, Zhang, H.: Need for a traceable efficiency determination method of nacelles performed on test benches. Measurement: Sensors 18 (2021), 100159.

Viallon, J. (...), **Niederhauser, B.:** Final report, ongoing key comparison BIPM.QM-K1, ozone at ambient level, comparison with METAS, July 2020. Metrologia 58 (2021), 08012, 11pp.

Tancev, G.: Relevance of Drift Components and Unit-to-Unit Variability in the Predictive Maintenance of Low-Cost Electrochemical Sensor Systems in Air Quality Monitoring. Sensors (2021), 21, 3298, 18pp.

Tancev, G., Grasso Toro, F.: Sequential recalibration of wireless sensor networks with (stochastic) gradient descent and mobile references. Measurement Sensors 18 (2021), 100115.

Vasilatou, K., Wälchli, C., Koust, S., Horender, S. (...), Auderset, K.: Calibration of optical particle size spectrometers against a primary standard: Counting efficiency profile of the TSI Model 3330 OPS and Grimm 11-D monitor in the particle size range from 300 nm to 10 μm . Journal of Aerosol Science 157 (2021), 105818, 12pp.

Vasilatou, K., Lieberherr, G., Auderset, K. et al.: Assessment of real-time bioaerosol particle counters using reference chamber experiments. Atmospheric Measurement Techniques 14 (2021), 7693-7706.

Conference contributions and papers

Assi, F.: Strassenverkehr aus der Perspektive der Metrologie. Strassenverkehrsrechtstagung Universität Fribourg, 21.6.2021.

Auderset, K.: Vorstellung LAPAZ. VDI/DIN-Kommission Reinhaltung der Luft. (online), 14.1.2021.

Basic, N.: Physics of sparkle and graininess. Workshop BxDIFF "High precision BRDF Measurements" (online), 9.12.2021.

Bernasconi, J.: Unsicherheitsbestimmung der Reflexionsmessungen von Fahrbahnoberflächen. Licht 2021 (online), 22.3.2021.

Bircher, B.: Methods for traceable compensation of machine geometry deviations in industrial computed tomography. dXCT Conference, NPL (online), 18.5.2021.

Bircher, B.: X-ray CT for AM: Towards traceable porosity defect measurements using digital twins. euspen SIG, Advancing Precision in AM (online), 22.9.2021.

Bissig, H.: Lowest traceable flow rates in microfluidics with process-oriented liquids and response time characterization. Precision Liquid Handling Workshop, CSEM, 24.11.2021.

Blattner, P.: Recent activities of the CIE. Australian Lighting Research Conference (online), 9.2.2021.

Blattner, P.: The International Commission on Illumination (CIE) and Aspects of Measurement Uncertainty in Photometry. SID DisplayWeek (online), 17.5.2021.

Blattner, P.: Overview of Activities of the International Commission on Illumination (CIE). 2021 International Conference on Display Technology – Beijing (online), 30.5.2021.

Braun, J.: Design and characterization of the programmable and time variant impedance. Final Workshop Z-NET (online) 15.10.2021.

Bühlmann, T.: Traceable reference gas mixtures for halogenated VOCs developed within the framework of the EMPIR project MetClimVOC. GAW Symposium (online) 28.6.2021.

De Huu, M.: Revision of the large water meter test rig. Euramet TC Flow meeting (online), 31.8.2021.

De Huu, M.: CCM.FF-K1.2019 first technical discussion. Euramet TC Flow meeting (online), 31.8.2021.

De Huu, M.: Introduction to hydrogen flow metering. Welmec 33rd WG10 meeting (online), 22.9.2021.

Frei, F.: Fricke Dosimetry as a Primary Standard and Reference for Absorbed Dose to Water in Ultra High Pulse Dose Rate Electron Beams. FRPT Conference 2021 (online), 1.12.2021.

Frigo, G.: Analysis and representation of non-stationary signals in inertia-reduced power grids. RTE Seminar, 26.3.2021.

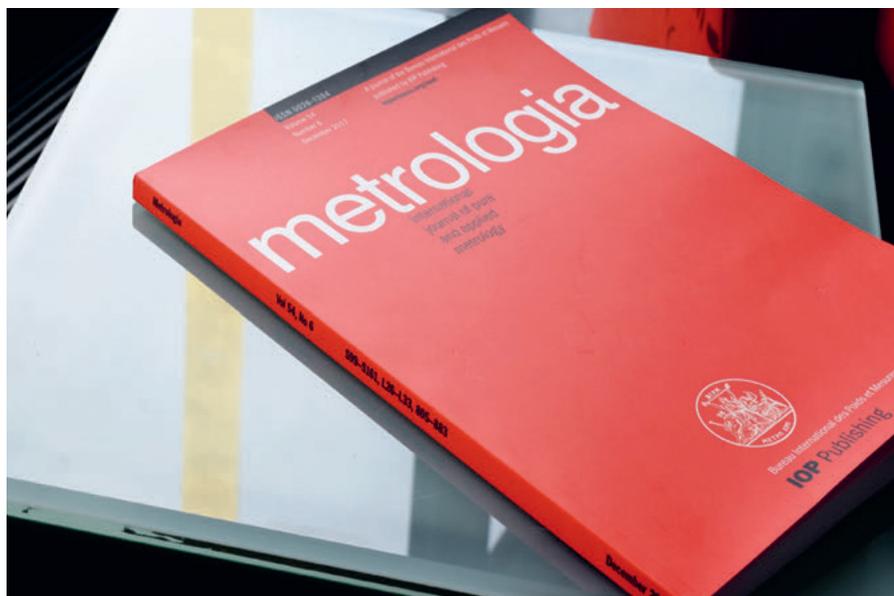
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Horender, S.: Vorstellung PALMA. VDI/DIN-Kommission Reinhaltung der Luft (online), 14.1.2021.



- Husmann, D.:** *Dissemination of SI-traceable optical frequencies at 1572 nm.* EMPiRTiFOON Stakeholder Workshop (online), 10.2.2021.
- Husmann, D.:** *Using the Swiss academic fibre network.* Joint ÖPG/SPS Annual Meeting SPS 2021, Innsbruck, 1.9.2021.
- Husmann, D.:** *Establishing a metrology optical fibre network to disseminate high accuracy optical frequencies through the Swiss academic fibre network.* NCCR-QSIT Seminar, 20.10.2021.
- Iturrate, M.:** *Traceable reference gas mixtures to calibrate analyzers used to measure atmospheric VOCs.* EURACHEM (online), 18.5.2021.
- Iturrate, M.:** *Metrology for Climate relevant Volatile Organic Compounds – MetClimVOC.* CIM 2021 (online), 8.9.2021.
- Jeanneret, B.:** *Load Compensation Bridge for Pulse-Driven Josephson Junction Arrays.* CIM 2021 (online), 7.9.2021.
- Lauterbach, K.:** *IEC 61000-4-3: Update über "Electromagnetic field immunity test".* 59. Sitzung PEGESS (online), 17.3.2021.
- Meli, F.:** *Controlling microfluidic device quality: measurement challenges.* Microfluidics Association Workshop (online), 28.1.2021.
- Meli, F.:** *Traceable sub-microfocus X-ray focal spot reconstruction by circular edge analysis.* dXCT Conference, NPL (online), 19.5.2021.
- Mester, C. / Braun J.:** *Eignungsprüfung – wurde wirklich so kalibriert oder geprüft wie spezifiziert? Beispiel: Prüfung von Elektrizitätszählern.* 10. VDI-Fachtagung Messunsicherheit, Erfurt, 15.11.2021.
- Niederhauser, B.:** *Metrologie, METAS, Terminologie, Messunsicherheit, Konformität und Atemalkoholmessung.* Master Forensik, ZHAW Winterthur, 13.12.2021.
- Overney, F.:** *Impedance simulator for the calibration of LCR-meter in its low impedance range.* CIM 2021 (online), 7.9.2021.
- Overney, F. / Jeanneret, B.:** *AC measurements on QHE devices.* GIQS stakeholder workshop. (online) 15.12.2021.
- Pascale, C.:** *Improved high-quality data of volatile organic compounds thanks to metrological development.* IGAC (online), 12.9.2021.
- Pascale, C.:** *Measurement uncertainty for VOC analysis.* Master: Analytical Strategies, ETH Zürich, 15.10.2021.
- Pythoud, F.:** *Messmethode für 5G-Basisstationen.* Meeting Cercle Air, Bern, 9.11.2021.
- Pythoud, F.:** *Konformitätsbeurteilung von 5G Basisstationen.* 10. VDI-Fachtagung Messunsicherheit, Erfurt, 15.11.2021.
- Pythoud, F.:** *Messmethode für 5G-Basisstationen.* 60. PEGESS Sitzung, Biel, 17.11.2021.
- Stölting, K.:** *Nucleic Acid Metrology: Ensuring reliable and Comparable nucleic acid measurements.* SGKC Neuchâtel, 10.9.2021.
- Stölting, K.:** *Nucleic Acid Metrology.* Eröffnung Biologielabor am METAS, Wabern, 11.11.2021.
- Stuker, F.:** *sensLAB: Bewegungs- und Präsenzsensoren auf dem Prüfstand.* Licht 2021 (online), 24.3.2022.
- Stuker, F.:** *sensLAB: Testing Motion and Presence Sensors for Smart Lighting.* CIE 2021 Midterm Meeting and Conference (online), 28.10.2022.
- Tancev, G.:** *Optimizing Characterization and Recalibration Procedures for Low-Cost Sensors in Air Quality Monitoring.* GAW Symposium (online), 28.6.2021.
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- Vasilatou, K.:** *The Organic Coating Unit, a system for reproducible generation of secondary organic matter aerosol.* Swiss Aerosol Group (online), 2.11.2021.
- Vasilatou, K.:** *Comparison of particle number concentration standards between METAS and NMII/AIST at 1, 10 and 100 cm⁻³ (CPC calibration).* CCQM (online), 3.11.2021.

