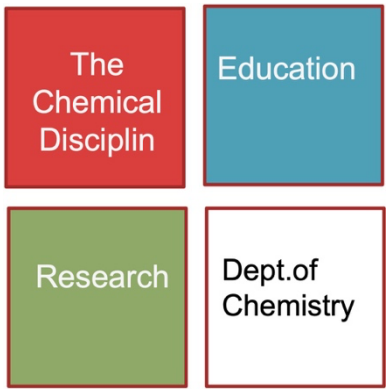
Strategy for Department of Chemistry 2023-2030.

1. Overarching vision for the Department



Chemistry is essential: Achieving a sustainable future and quality of life depend critically on our detailed understanding of matter and life at the molecular level and the ability to translate this insight into efficient and environmentally friendly solutions.

Department of Chemistry is committed to developing and forwarding the chemical perspective and body of knowledge and thereby, to work relentlessly toward a sustainable and scientifically literate society.

2. Core values

Who and what we, of the Department of Chemistry, are and want to be, is shown in and by our shared core values:

- Critical, independent thinking
- Curiosity and creativity in our approach to knowledge and technology
- Courage to set important and ambitious goals, and endurance in their pursuit
- Strive for excellence in what we do
- Culture of safety
- High standard of ethics reinforced by research integrity and accountability
- Collegial working and learning
- Diverse and inclusive community where all are treated equitably and with respect

3. Our vision

The Department of Chemistry

- Constitutes an ambitious, curious, collaborative, well-connected and open scientific community
- Creates fundamental and applied chemical insight through research of the highest ethical and scientific standards
- Provides important contributions toward sustainable energy and chemical manufacturing, chemistry from renewable resources, and chemical technologies for good health
- Competes and regularly wins on the most prestigious national arenas and in European programs for research funding
- Provides a modern and well-run research infrastructure, including national platforms in prioritized technologies, that evolves in step with prioritized needs in research and education and complementing opportunities at external research facilities
- Constitutes a nationally recognized and evolving learning environment
- Educates in the chemical competences and the molecular perspective, in chemistry programs, in thematic programs where chemistry plays a major role, and with basic insight when chemistry is one of the lesser yet essential components
- Benefits from synergy between strategic research programs and main educational responsibilities

- Promotes passion for chemistry by challenging, enlightening, and engaging students and the broader audience with the possibilities and understanding offered by chemistry
- Turns chemical insight into innovative solutions to the benefit of society, with the occasional spin-off company as a visible result

4. Research strategy

Research is the kingpin in the activities at the Department of Chemistry: we research; we educate based on research; we disseminate research results; and we innovate based on results from our research. The research is conducted within four groups that serve and execute different aspects of the department strategy. Our groups are

- Bioresources and Pharmaceutical Chemistry
- Sustainable Energy Carriers, Chemicals, and Materials
- Chemistry in Medical Technology
- In Silico Molecular Exploration and Design

In accordance with our Vision for the department and as a matter of strategic priority, we seek synergy between the research program and our main educational responsibilities, i.e. the disciplinary program in Chemistry (BSc, MSc, PhD) and multi-disciplinary programs in Nanoscience and -technology (BSc, MSc), Pharmacy (integrated master/professional degree), Medical Technology (integrated master), and Energy (integrated master). Examples of such synergies are recruitment of talented students to our research, highly competent and motivated instructors sharing insight from the forefront of knowledge, alliances with regional industry for education and research, dual use of basic and advanced infrastructure, and our graduates as agents for change in society. As a consequence, each of the research groups is responsible for offering challenging research opportunities to students within a specific and thematically-related program, in addition to the chemistry program.

4.1 Two strategic research areas at the department: Sustainable Energy and Chemical Production, and Molecular Life Science

After briefly relating these (broad) research areas to our research groups over the next two paragraphs, the research focus of each group and thus their specific contributions to each area is presented with emphasis on present activities and strategic directions for 2022-2030.

Close-to all of the activity in the *Sustainable Energy Carriers, Chemicals, and Materials* group belongs in the first research area, **Sustainable Energy and Chemical Production**. The *Bioresources and Pharmaceutical Chemistry* group performs research into sustainable and novel high-value products from bioresources, with a focus on the molecular life science perspective and applications to food, feed, and health. The biorefinery concept is a relevant platform for mutual projects between these two groups. The *In silico molecular exploration and design* group develops models and methodologies for understanding and designing efficient catalysts for sustainable energy carriers and chemical production, in close collaboration with the *Sustainable Energy Carriers, Chemicals, and Materials* group.

The **Molecular Life Science** area receives strong contributions from three of our four research groups: *Bioresources and Pharmaceutical Chemistry* group, *Chemistry in Medical Technology*, and *In Silico Molecular Exploration and Design*. Early drug discovery is a shared theme

between these groups. The *Bioresources and Pharmaceutical Chemistry* group has a strong focus on the discovery of biologically active compounds toward therapeutic applications, while the *Chemistry in Medical Technology* group has a diagnostic focus. The drug design activities in the *In Silico Molecular Exploration and Design* group are closely linked to the *Bioresources and Pharmaceutical Chemistry* group for organic synthesis, compound characterization, and protein force field development, whereas projects on biomembranes benefit from the expertise in solid state NMR present in the *Chemistry and Medical Technology* group and synthesis of membrane active peptides in the *Bioresources and Pharmaceutical Chemistry* group.

4.2 Sustainable Energy Carriers, Chemicals, and Materials

The group's *Vision* is to be a driving force in the development of low-carbon, green, and sustainable solutions within renewable energy and chemical manufacturing. To this end, the group develops strategies and processes for production of low-carbon energy carriers, fuels, materials, and renewable bulk and fine chemicals.

Low-Carbon Energy Carriers. *How can we develop insight and new functional molecules, materials, and processes to provide energy carriers which contribute little or no carbon dioxide to the atmosphere?* To develop **sustainable biofuels** is a long-standing line of research in the group. Lignin is by far the most abundant natural source of renewable aromatic hydrocarbons, and with the Bergen lignin-to-liquid (LtL) process, researchers in the group have pioneered the depolymerization and partial deoxygenation of lignin. Working to reach complete deoxygenation of the LtL oil under mild conditions, the group draws upon its combined competences in organic process development, catalysis, and structural chemistry. The department is excellently positioned to expand its activities within development of sustainable, biobased alternatives to both energy carriers and petrochemicals, and to further categories of waste and non-traditional, cheap feedstocks to foster development of circular economies. The lignin-based process development and catalytic deoxygenation have received financial support from multiple sources (EU, RCN, industry).

Carbon-free energy carriers such as **hydrogen and ammonia** are likely to play greater roles in a future, sustainable energy economy. Advanced materials will help realize this shift, for instance as catalysts in the production of these carbon-free molecules, or by separating and purifying them. Ammonia's potential as a non-explosive and energy-dense alternative to hydrogen is hampered by the high-pressure, high-temperature Haber-Bosch production process. Combining our competence in catalysis, nanoporous materials and physical chemistry, the long-term strategy of the group is to develop an alternative to Haber-Bosch process based on electrosynthesis of ammonia from nitrogen in the air, and water under ambient conditions. From a humble start in 2020, the effort to design and synthesize molecular nitrogen fixation catalysts relying on chemical reductants, augmented by catalyst immobilization and electrochemical regeneration to achieve overall electrosynthesis of ammonia, has attracted considerable public and private funding and is a cornerstone of Norwegian Centre for Hydrogen Research (HyValue, an FME center), involving a range of academic and industrial partners.

Sustainable Chemicals, Materials, and Processes. *How can we develop insight and new functional molecules, materials, and processes to provide sustainable chemicals and processes*

to meet major societal challenges? Sustainable chemical production at an industrial scale requires sustainable resources, and the attention is increasingly turning to bioresources, including carbon dioxide. Within the framework of Carbon Capture, Utilization and Storage (CCUS), the group has contributed to the discovery and exploration of some of the best-performing solid adsorbents (Metal-Organic Frameworks) available for capturing carbon dioxide. Once captured, CO_2 is an inexpensive, green, and readily available C1 feedstock. The group has developed a series of sustainable catalysts for producing **CO_2-based polymers** with epoxide comonomers. The focus on polymer properties will be expanded, with a much-increased focus on incorporation of monomers from a range of advanced bio-based feedstocks alongside CO_2, in addition to full recovery of the catalysts themselves. The biorefinery concept is central to achieve a viable circular economy for biobased chemical resources. This includes the extraction of low-volume high-value compounds (in collaboration with the *Bioresources and Pharmaceutical Chemistr*y group), conversion of major fractions to platform chemicals, and bulk biofuel components as described above. Recent extensions of the biofuel activity include carbohydrate conversion, in particular hemicellulose sugars to furfural and hydroxymethylfurfural (HMF), with funding by the RCN in several industry-led projects with the Arbaflame biorefinery.

A central research challenge for the next decade, is to develop catalysts and processes that transform renewable resources to platform building blocks that can be used by the (petro-) chemical industry. An attractive resource is oil from plants and algae, and the group develops catalysts for decarbonylative dehydration of fatty acids of such oils to 1-alkenes. Similarly, olefin metathesis holds enormous promise in the cleavage of unsaturated fatty acids to 1-alkenes, and in green transformations of olefins. Thus, catalyst performance and stability remain a long-term research theme in the group. Within olefin metathesis, the new tools developed by the *In silico Molecular Exploration and Design* group hold great promise for the design of robust catalysts for cleavage of fatty acids to α-olefins via ethenolysis - an attractive, long-standing goal that would enable atom-economic valorization of plant, fish, and algae oils at ambient conditions. Marin bioresources are of particular importance to Norway and the coastal region, and our focus on marine biomass aligns excellently with the UiB focus on marine research opportunities.

Renewable electricity is increasingly replacing heat as the preferred energy input to chemical processes. This allows for better energy efficiency, in particular when combined with catalysis to minimize over-potentials. **Electrocatalysis**, i.e., the combination of electrochemistry and catalysis, may give sustainable access to energy carriers and other chemicals not accessible by regular catalysis. As a matter of strategic priority, the department will establish electrocatalysis as a research area in close interaction with existing activities in the *Sustainable Energy Carriers, Chemicals, and Materials* group. This includes a new recruitment, reorientation of current group members, and internal collaboration within the department. The research group will also explore the potential of materials (MOFs, nanoparticles, etc.) in electrocatalysis and their electrochemical properties.

4.3 Bioresources and Pharmaceutical Chemistry

The group aims to discover and characterize molecules of natural and synthetic origin that have the potential to mitigate global challenges related to food, feed, and health on a molecular level. Through the combined expertise within natural products chemistry,

analytical chemistry, organic synthesis, medicinal chemistry, and colloidal chemistry, the group performs research along the full chain from isolation, structure elucidation and synthesis of natural products, via sustainable and novel high-value products from bioresources to meet demands in food and feed, and to improved health through early-stage drug discovery and drug delivery. The group's expertise in analytical and semipreparative protocols to handle low concentrations of high-value compounds in complex matrices of natural origin is essential to applications to both sustainable bioresource development and bioprospecting. NMR spectroscopy and analytical chemistry allow discovery of novel structures from a variety of natural sources in addition to characterization of protein-ligand interactions. Recent natural product discoveries include flavonoids, isocoumarins, coumarins, dihydrostilbenoids, lignans, prenylated phenolic compounds, alkaloids, bicyclic lactones, and complex polyglycosylated compounds. The group's competence on the discovery of novel structures with desirable properties, both of natural and synthetic origin, is applied toward new antibiotics, antivirals and compounds targeting cancer and inflammatory lung diseases through addressing underexplored targets in early drug discovery projects as well as developing new drug formulations through nano-drug delivery systems.

Sustainable bioresources utilization. *How can we explore and create new sustainable high-value products from bioresources to tackle the challenges related to food, feed, and health for future generations?* Over the past decade the group has built competence on natural products from marine bioresources (seagrass, seaweed/macroalgaes and microalgae), as a strategic decision to complement our established strong international position on the discovery of biologically active natural products from terrestrial plants. Besides research on seagrass phenolics and their chemical ecology related to environmental gradients, a particular focus has been on harvested and cultivated seaweeds through RCN funded projects in collaboration with industry. The projects target basic research on extraction, isolation and chemical characterization at the molecular level, relevant to the sustainable development of marine life science ingredients and products. The research focus will be expanded to chemical ecology of seaweeds, tracing production of secondary metabolites back to environmental gradients.
The group has long-standing expertise on lipids in micro-algae, including screening of fatty acid compositions in algal strains and optimization of growth conditions for improved yields of EPA and DHA in algae intended for fish feed. One of our aims for the next decade is to target natural products from deep-sea fauna of hydrothermal vents and to contribute to developing an interdisciplinary UiB-platform for cultivation of deep-sea microorganisms for sustainable drug discovery purposes.

Advancing separation technologies. *How can we advance separation technologies to address the bottlenecks of preparative purification of high-value products from complex matrices within bioprospecting and bioresource utilization?* Creating high-value products from chemical compounds present in complex and composite biomass requires economically viable processes for isolation or, at least, up-concentration. This is particularly crucial for marine applications, where biomass originating from macroalgae, microalgae and sea grass pose completely different challenges compared to biomass from terrestrial sources. The group aims for national lead in advancing separation technologies for preparative purifications of high-value compounds from complex matrices within bioprospecting and bioresource utilization. More specifically, we aim to target low-molecular-weight compounds, with particular focus

on specialized molecules (secondary metabolites) from bioresources of interest to research and Norwegian industry.

Early-stage drug discovery and drug delivery. *How can we discover new antibiotics and antiviral agents by addressing underexplored targets as well as developing new drug formulations through nano-drug delivery systems?* Together with local and international partners, the group has established a platform to address fundamental questions on potential new targets for antibiotics. These activities have secured funding for the next 4-5 years. This platform will also be used to address fundamental questions on how small organic molecules can be designed to bind with high affinity to RNA, thereby opening for drug-discovery based on RNA targets, including antibiotics. Through our combined expertise in natural products chemistry, organic synthesis and medicinal chemistry, we will also address the global challenge of antimicrobial resistance by searching for novel antimicrobial compounds from marine and terrestrial organisms. The group is also involved in long-standing research collaborations on marine bioprospecting, in particular on the synthesis-driven optimization of bioactive marine natural products toward lead compounds in early-stage drug discovery. These activities have a clear innovation potential, and this will be in focus going forward. The innovation potential of drug delivery systems is also prominent, where our current research on drug formulations is focused on developing lyotropic liquid crystal nanodrug delivery systems for parenteral usage and lipid nanoparticles for delivering biologics and nucleic acid drugs. Our ambition for the coming years is to develop a nano-platform for delivering therapeutical nucleic acids including nucleic acid vaccine and mRNA with anti-cancer activity.

4.4 Chemistry in Medical Technology

The group conducts chemical research in the field of medical technology. The expertise of the group includes chemometrics, NMR spectroscopy, medicinal chemistry, flow chemistry, radiochemistry, medical imaging, and both organic and inorganic synthesis. The combined expertise is applied to research questions related to improved acquisition, analysis and modelling of spectroscopic data for medical applications, improvement of image contrast in magnetic resonance imaging (MRI) and positron emission tomography (PET), and advanced technologies for synthesizing and optimizing compounds for diagnostic and therapeutic purposes. The research is performed in close collaboration with medical research groups at UiB and Helse Vest. Our research vision is *Innovative solutions in medical technology based on chemical knowledge.* The strategic focus is on molecular imaging, analytical profiles for biological tissues, and biologically active molecules for diagnostic purposes, in addition method developments for data acquisition and processing.

Improved diagnostics through molecular imaging. Molecular imaging and in particular positron emission tomography (PET) is increasingly important to accurately diagnose diseases. With the founding of the Norwegian Nuclear Medicine Consortium in 2020, the Bergen node was entrusted with the development and implementation of novel radionuclides and radiopharmaceuticals. Our work focuses on developing methods for radiolabeling with ^{45}Ti and a new method for introduction of ^{18}F for labeling of peptides. The research group has recently developed a stepwise interplay between the non-radioactive (cold) methods and radiolabeling (hot) chemistry involving suitable functionalized multidentate chelators, ready to be anchored onto targeted peptides with the aim to efficiently shorten the extraction procedures. The group is also preparing peptide-chelator conjugates to support pre-clinical

PET imaging activities in the consortium. Furthermore, synthesis of biologically active molecules as probes for diagnostic monitoring of targeted drug administration is an important research area in the group. Strengthening of the research on radiopharmaceuticals (tracers) in combination with optimizing and development of methods for molecular imaging is a strategic priority in the group. We aim to establish the group among the world key developers of ^{45}Ti-based imaging agents and to pave the way for ^{45}Ti technology as common PET tracers, as well as to further explore other radiometal tracers, and to develop molecules for real-time monitoring of administered drugs using PET in combination with other modalities. Multimodal imaging has brought new perspectives into the field of molecular imaging. Combined PET/MR scanners for simultaneous acquisition, resulting in a combined functional and morphological image, have entered both clinical and preclinical applications. Targeting PET-tracers, combined with MRI and magnetic resonance spectroscopy (MRS) can contribute to further development in diagnostic capabilities when it comes to data acquisition. This can be supplemented with solid-state NMR studies of biopsies. Furthermore, improvement in data processing can be achieved by multivariate data analysis of the obtained MRS-spectral data. This package of combined methods and PET-tracers can contribute to improved diagnosis of tumors, demyelination, axonal loss, and various neuro-degenerative diseases.

Improved analytical profiles of body fluids for better understanding of physical and mental health. Developing methods for multivariate data analysis is an important part of the group's research activity. This includes topics like prediction error, model complexity validation and deconvolution of overlapping signals, primarily generated by chromatography, mass spectrometry and spectroscopy (NMR and vibrational). Applications include lipids, omega-3 fatty acids, cholesterol, and vitamin D, and their effects on health. One of the main challenges in such studies is the complexity, both in the chemical composition of samples, and the systems that are studied (*i.e.* all factors influencing physical and mental health). This requires advanced statistical and chemometric data handling. Development of new algorithms for multivariate data analysis, in particular within error prediction, model complexity validation and deconvolution of overlapping signals, will remain a research focus within the group, and with the ambition to contribute to important method developments in medical technology. In future projects we aim to expanded from our current work on vitamin D and lipids, to look at the role of neurotransmitters. Chromatography and mass spectrometry has been used extensively in the past, but as the department hosts Norway's leading NMR platform, more focus will be on extracting information from NMR profiles.

Development of techniques for obtaining high quality data. The group has applied a wide range of NMR-techniques, including solid-state NMR, diffusion-weighted NMR, and NMR-microscopy, to explore molecular interactions on surfaces, porous materials, and characterization of biological samples. Medical applications include studies of molecular interactions in lipid membranes using solid-state NMR, characterization of drug delivery systems using diffusion-weighted NMR, and diffusion-weighted NMR-microscopy of brain metabolites. The inclusion of NMR-microscopy has initiated translational research in molecular imaging, which is based on our group's expertise in method development within studies of molecular interactions in porous materials. This has enabled more collaboration with the clinical MR research community at HUS, in particular the Bergen fMRI group, where our current project focuses on development of improved techniques for in vivo diffusion-weighted MR-spectroscopy in a translational research setting. Improvement and development

of methods for medical imaging and in vivo spectroscopy will continue to be an important part of the research activities. The focus remains on characterization of porous materials using NMR and MRI, in particular methods based on multidimensional diffusion techniques.

4.5 In silico Molecular Exploration and Design

The group conducts research in chemistry and biophysics by developing and applying computational methods to design organometallic catalysts and drug-like compounds, and to explore mechanisms of membrane protein association and supramolecular lipid structures. Central to our methods development are automation and data-driven approaches in molecular pattern discovery and design, computational chemistry workflows, and high-fidelity model calibration. Taking advantage of its leading edge the group will extend its activities towards enhanced and automated methods for *de novo* design and for validation and calibration of molecular mechanics force fields. The group will build on its long-standing expertise in the elucidation of complex molecular mechanisms to investigate electrocatalytic processes, organometallic catalysis, and the allosteric regulation of protein dynamics by membrane lipids. The broad range of competences present in the group – from high-end *ab initio* quantum chemistry and mechanistic studies to protein bioinformatics and force-field-based simulations of large systems – is a major advantage when reaching for our vision: *High-fidelity computational models for molecular mechanisms, patterns and design.*

The group has a long-standing and strong expertise in **molecular design** and **predictive biomolecular models**, and most of its ongoing activities are externally funded with a 3 to 5 years horizon. Future activities will thus be centered around those two themes which critically rely on a broad range of theoretical frameworks. This should be born in mind in future recruitments. For the same reason, the strong links between the group and the Computational Biology Unit should be maintained. The group will strive to continue making its developed software solutions available Open Source, to use sustainable and best coding practices, to share its results following the FAIR principles and increasingly engage in Open Science initiatives. To support the group in these efforts, the recruitment of personnel with a software engineering background is critical.

Molecular design: *How do we navigate chemical space to identify compounds with desired properties?* The group will focus its development of *de novo* molecular design along two directions, both funded for the next 5 years in projects *eHACS* and *iCat4Bio*. One line of research will focus on reducing the need for time-consuming and manual post-*de novo* refinements of designed molecules by developing visual data science approaches offering on-the-fly and fast interaction with the users, in collaboration with the *Bioresource and Pharmaceutical Chemistry* group, as well as machine-learning models that accelerate local optimization tasks. As a second line of research, we will create a fully self-driven and automated computational-experimental molecular development platform by integrating *de novo* molecular design and robot-driven experimental molecular and process optimization (see Infrastructure).

The advanced design tools developed by the group will be applied in collaboration with the *Sustainable Energy Carriers, Chemicals, and Materials* group to develop robust and selective catalysts for olefin metathesis reactions in challenging environments, such as transformation

of protected biomolecules in water-rich, bio-relevant environments. Moreover, we will expand our mechanistic investigations of CO_2 and N_2 reduction to include more sophisticated and accurate theoretical models pertaining to the overall electrocatalytic processes (to support experimental efforts to develop a benign, water-based electrosynthetic ammonia process in Bergen).

Early drug discovery. The recently funded five-year *eHACS* program to complement our de novo design methods with new capabilities will be employed to the design of organic drug molecules with complex structures characterized by many fused rings. Such structures need to be 3D-like bind to the larger and more globular-shaped pockets of many difficult-to-drug targets. Candidate ligands will be designed for difficult-to-drug targets relevant for antibiotics and cancer treatment. Promising ligands will be synthesized by the *Bioresources and Pharmaceutical Chemistry* group and tested at Department of Biomedicine. Longer term, our goal is to expand these efforts at addressing difficult-to-drug targets to peripheral membrane proteins (PMP), building on our long-standing expertise in modelling of protein-membrane interfaces and our leading edge in the field to develop methods for the design of (1) inhibitors of interfacial protein-membrane interactions and, (2) design of peptides with antifungal or antibacterial activities. Together with the *group of Bioresources and Pharmaceutical Chemistry*, we will pursue our efforts in the rational design of drug candidates for the treatment of chronic lung inflammation, and to explore commercialisation opportunities.

Biomolecular modelling. *How do we achieve mechanistic understanding of biomolecular systems through reliable models?* Building on our success with High-fidelity predictive force fields for lipids, we will develop methods for rapid automated calibration of force fields of biomolecular systems characterized by wide, highly dynamic conformational ensembles. These include, e.g., intrinsically disordered proteins and saccharides. For these systems we will also, building on the success of the NMRlipids Project, create open databanks of quality-evaluated simulations and develop machine learning methods to extrapolate from such databanks to the structure, dynamics, and materials properties of the corresponding intrinsically disordered biomolecular systems.

For molecular simulations, it is advantageous to use multiscale approach alternating between models at different levels of resolution to take advantage of the computational efficiency of the low-resolution models for slow events and of the atomistic level of details of all-atoms force fields. Implicit membrane models and coarse grain models are also particularly appealing for comparative analyses spanning entire protein families, or multiple lipid compositions. We plan to take advantage of the availability of high-throughput data to propose a new approach for force field validation, providing statistical estimates of their predictive power.

Using protein bioinformatics, simple mathematical models and deep learning on large PMP datasets we seek to develop predictive models able to differentiate the membrane-binding site of PMPs from the rest of their surface. This will unlock high-impact downstream opportunities in biology and medicine, such as the possibility to tailor-make PMPs with desired properties and to design, rationally, inhibitors for protein-membrane interfaces. Our work will be informed by experimental data present in public databases but also and most importantly by our international and local collaborators using lipidomics, biophysics and (solid-state) NMR. Further we aim at modeling interfacial mechanisms such as e.g. lipid uptake/release by

phospholipases and lipid transfer proteins, as well as understanding the more general role of membranes as allosteric effectors.

5. Infrastructure

Crucial to both education and research at the Department of Chemistry is access to **modern and well-equipped chemistry laboratory space of sufficient area and near office spaces**. Our primacy location at the Science Building was inaugurated in 1977 and is by now largely outdated when it comes to technical standard. There are well advanced plans for full refurbishment of the Science Bldg as part of a major campus modernization program that includes much of the MN faculty – *Nygårdshøyden Sør* – but funding- and go-ahead decisions are yet to be obtained. On this backdrop it is extremely important and valuable that the Department of Chemistry is presently building a completely **new section of 400 m^2 of prime-quality chemistry laboratories** at the top user floor of the Science Bldg, including a dedicated technical support system. Our most ventilation-reliant activities will move into this area in 2023, while releasing most of our present laboratories at the 2nd floor. This allows us to pursue with confidence the ambitious strategic goals set out in the preceding section.

Our research activities depend heavily on access to advanced scientific instrumentation, maintained and run by a competent staff. With rapidly raising cost levels of acquiring and running experimental facilities, the department needs to make well-considered decisions about which needs are adequately served through access to external facilities, including national and European facilities, and which needs to be provided by the department. Own facilities that serve a wide selection of users are organized, funded, and staffed at the department level, while instrumentation that serves a narrower, more specialized function remains the responsibility of the research group in question. Our main instrumental platforms include NMR spectroscopy, mass spectrometry, gas- and liquid chromatography, and vibrational spectroscopy.

Department of Chemistry hosts the Norwegian NMR Platform (NNP), with the Bergen node offering access to two high-resolution instruments for liquid NMR studies (at a proton frequency of 850 and 600 MHz, resp.), and a versatile multiprobe 500 MHz instrument for solid-state (MAS) and diffusion spectroscopy, and micro magnetic-resonance imaging. During 2023, these instruments will be co-located at the NNP-building at some 8-minutes walking distance from the Science Bldg. To recover and reuse the liquid helium used for cooling the superconducting magnets, a recovery and compression unit for helium will be established, thereby preserving a global resource in shortage and at the same time ensuring stable operational conditions. While the NMR platform will be relocated to the Science Bldg as part of the Nygårdshøyden Sør program, it is highly desirable for the department to acquire a low-field (400 MHz) multi-nuclear instrument close to support our synthetic activities. While our participation in the NNP-2 project secures a timely upgrading of the 850 MHz-instrument half-way into the time horizon of the present plan, the department needs to develop a comprehensive action plan for the NMR facility and access to a wide range of NMR experiments, including which capabilities may be adequately covered through our partners within the NNP.

As a matter of strategic priority, the department is in the process of establishing state-of-the-art facilities for high-throughput experimentation (HTE@UiB) in both batch and flow modes,

through strategic funding from UiB and the MN-faculty. Automation of sample preparation, synthesis, and on- and in-line chemical analyses will significantly speed up the development of new compounds and processes across the department's activities. This opens for more ambitious projects and a competitive edge. The department aims to become the leading research environment for HTE-enabled discoveries in Norway and works systematically with our partners to establish a versatile and open national laboratory that forges large-scale optimization and artificial intelligence methodology into tools for Norwegian researchers in industry and academia to design and optimize functional compounds for a wide range of applications.

The Department of Chemistry relies heavily on resources for high-performance computing and storage (HPC). More specifically, the *In silico Molecular Exploration and Design* group is among the largest users of the national HPC infrastructure and is critically dependent on these resources. It will be important for the group to seek access to European infrastructure (e.g. EuroHPC JU) to cover some of these needs, to lessen the vulnerability associated with changing boundary conditions for the national HPC program.

6. Strategic initiatives within bachelor and master education

Our core values and the overarching vision for our department together form a detailed and ambitious framework for our educational philosophy and programs. Our candidates acquire solid professional knowledge and practical skills, get trained in professional and ethical reflections on current topics, and develop their abilities to solve challenges. Our candidates should be able to work well both individually and in collaborations. Close coupling to research and societal challenges makes our candidates reflective, innovative, versatile, and highly competent professionals. The Department of Chemistry welcomes a diverse student body who develop through active forms of learning, within a safe framework and in an open professional community. Our collegium of teachers reflects on own practice and educational challenges and works with the development of teaching methods and evaluation methods.

The Chemistry Laboratory is an essential and resource-demanding Learning Arena in all our educational programs. The typical science learning goals of laboratory courses, which are highly relevant for chemists of tomorrow, include enhanced mastery of science subject matter, increased understanding of the complexity and ambiguity of empirical work, practical skills, and teamwork abilities. However, while the typical "recipe"-model for laboratory courses strengthens the students' skills in adhering to instructions and following guidelines, it seems less effective in fostering qualities like critical and innovative thinking, i.e. essential elements in the student's future professional life. In the current strategy period, the department will focus on developing laboratory-based learning and teaching with the aim to promote skills such as critical and innovation thinking, foster student engagement by inquiry-led learning as equal participants of the learning community, and insight in the research process. Halfway into the strategy period, and based on own preliminary explorations, we aim to include haptic augmented-reality models in complement with the course laboratory, to expose the students to a wider set of experimental and environmental conditions. Given the importance and transferability of such developments, we aim to establish a national center (SFU) to pursue and share these efforts toward reinventing the chemical laboratory as an arena for learning.

A critical element in our work to improve the educational quality is the continuous professional development that grows from lecturers collaborating and engaging with colleagues to update their knowledge, skills, and methodology. Learning is enhanced by continual evidence-based experimentation and evaluation, enlightened by current literature on learning and didactics. TA's and technical staff are important partners in teaching and learning based on the level of instructor experience and they are essential to developing the chemistry laboratory as learning arena.

The students are key contributors in quality processes at universities, and a key component of student engagement is the student voice in institutional governance, through student feedback, student representation, and student approaches to learning, learning spaces, and learning development. Our ambition is to increase the involvement of students in the educational quality work. The partnership between students and faculty/department should be based on respect, reciprocity, and shared responsibility in learning. To increase the student's sense of belonging and engagement in the quality work, we will work to increase teacher awareness of implicit bias in teaching and actively work to include all students at all levels.

Student recruitment relies on the quality of the program and to what extent the program meets expectations and attains visibility toward future employers. Drawing on our experience with internships in the Integrated master's program in Medical Technology, we aim to increase the exposure to industrial applications and the direct interaction between relevant industries and students in all our programs.