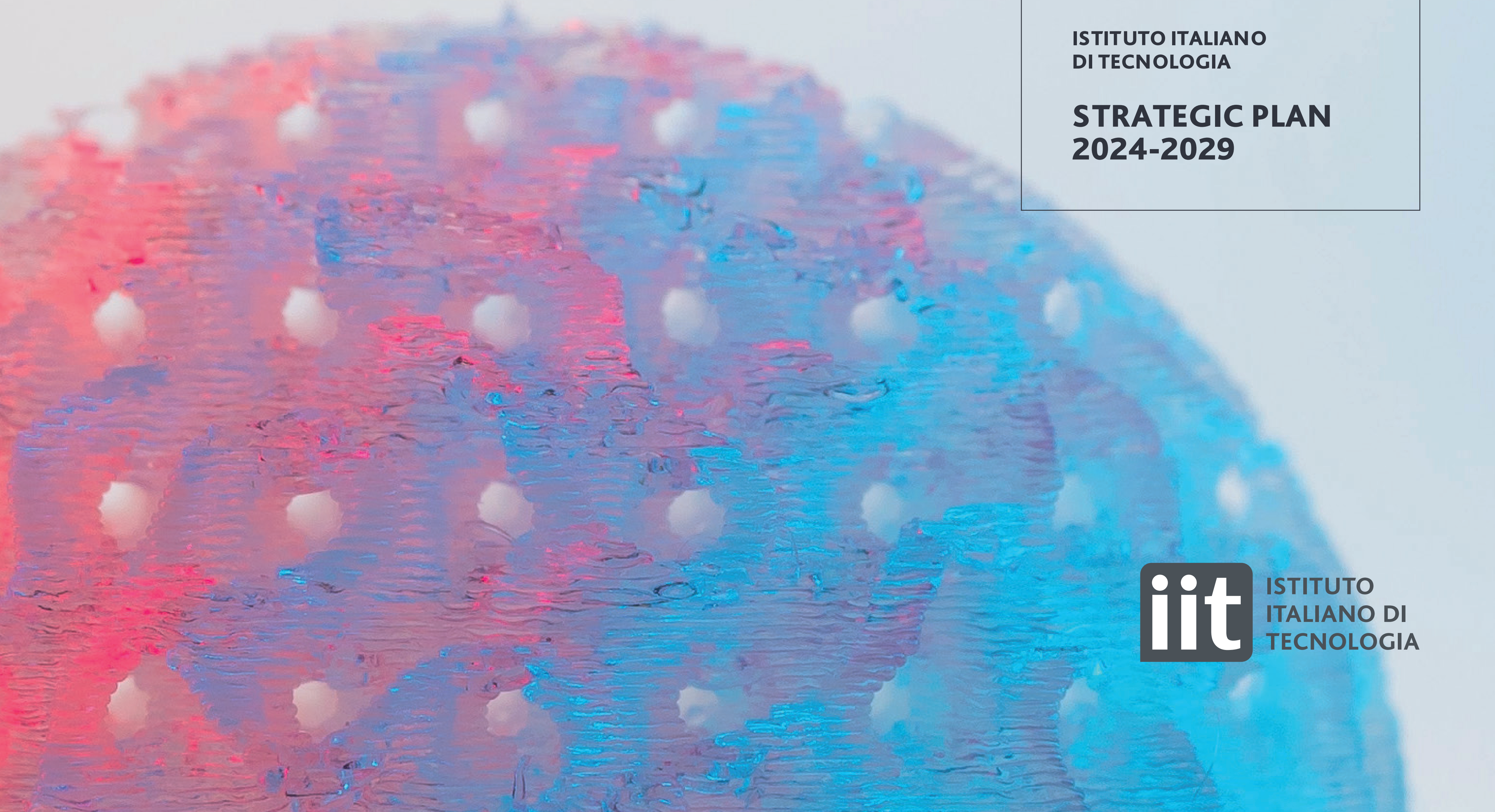

ISTITUTO ITALIANO
DI TECNOLOGIA

STRATEGIC PLAN 2024-2029

ISTITUTO ITALIANO DI TECNOLOGIA

A plan that prioritizes AI for Healthcare and Earthcare

The Science of today is the Technology of tomorrow.

Edward Teller – American-Hungarian Physicist (1908-2003)


iit ISTITUTO ITALIAN


O DI TECNOLOGIA

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Executive Summary

The 2024-2029 Strategic Plan of the Italian Institute of Technology recognizes that artificial intelligence (AI) offers increasing opportunities to impact scientific discovery and technology development. This requires a computation and data management program along with the development of AI methods for science to support our traditional experimental research, namely: robotics, materials science, and biology.

The application of AI to science promises to accelerate scientific discovery, lower costs, identify knowledge gaps, and boost creativity by freeing scientists from tedious repetitive tasks.

This new Strategic Plan leverages IIT's curiosity-driven excellent science (Blue Sky Research program) with an investment of about 1/3 of the total research budget. This Strategic Plan also introduces five new cross-domain Flagship Programs to increase the chances of transferring knowledge and technology to the market.

With this same ambition, IIT's Technology Transfer's actions will increase our efforts in education for entrepreneurship and launch systematic dialogues with companies and healthcare institutions.

Our Flagship Programs are centered on the following themes:

- Technologies for Sustainability, which extends our recent initiative on sustainability challenges such as biomaterials, water remediation, and robots in agriculture;

- Brain and Machines, which aims to apply computational tools to understand how brain circuits give rise to the amazing cognitive and motor capabilities of humans. Robots and embodied AI help to model data obtained with neural electrical and optical recording as well as stimulation technologies;

- Teaching Science to Computers, which focuses on developing physics-informed machine learning, addressing challenges of reliability and learning from small amounts of data;

- RNA Technologies, which leverages IIT's pioneering research on RNA for precision medicine, using AI to analyze and understand processes in the cell;

- Technologies for Healthy Living, which brings together several technical advances in support technologies for the aging population.

Green chemistry promotes the invention, design, and use of chemicals and processes to reduce or eliminate the use and production of polluting or hazardous substances.

The concrete objectives of the Flagship Programs include intelligent interactive robots (Brain and Machines), new ways to drug the undruggable (RNA Technologies), soft ecorobots for agriculture (Technologies for Sustainability), efficient and trustworthy AI (Teaching Science to Computers), and wearable solutions to support a large eldering population (Technologies for Healthy Living).

Cutting-edge science and technology depend on the ability to attract and retain talent. A major component of our plan is thus designed to value human capital, individual education, and career paths, and to increase our attractiveness and further our internationalization.

On average, our staff are very young, so a constant turnover requires the creation of opportunities for scientists to move for career progression.

Transversal education covers all aspects of technology development, and is our key initiative for training a new generation of professionals for academia or industry. AI will be another fundamental asset in our scientific training.

Furthermore, the Strategic Plan includes two major infrastructural actions: i) strengthening IIT's Network Centers in Italy (see "Appendix 2: Infrastructure & Centers" on page 62) and ii) strengthening our international links to key countries and institutions by following and expanding our existing model of IIT Outstations in the USA. They are the seed of the IIT Global internationalization plan (see "People and Higher Education" on page 42).

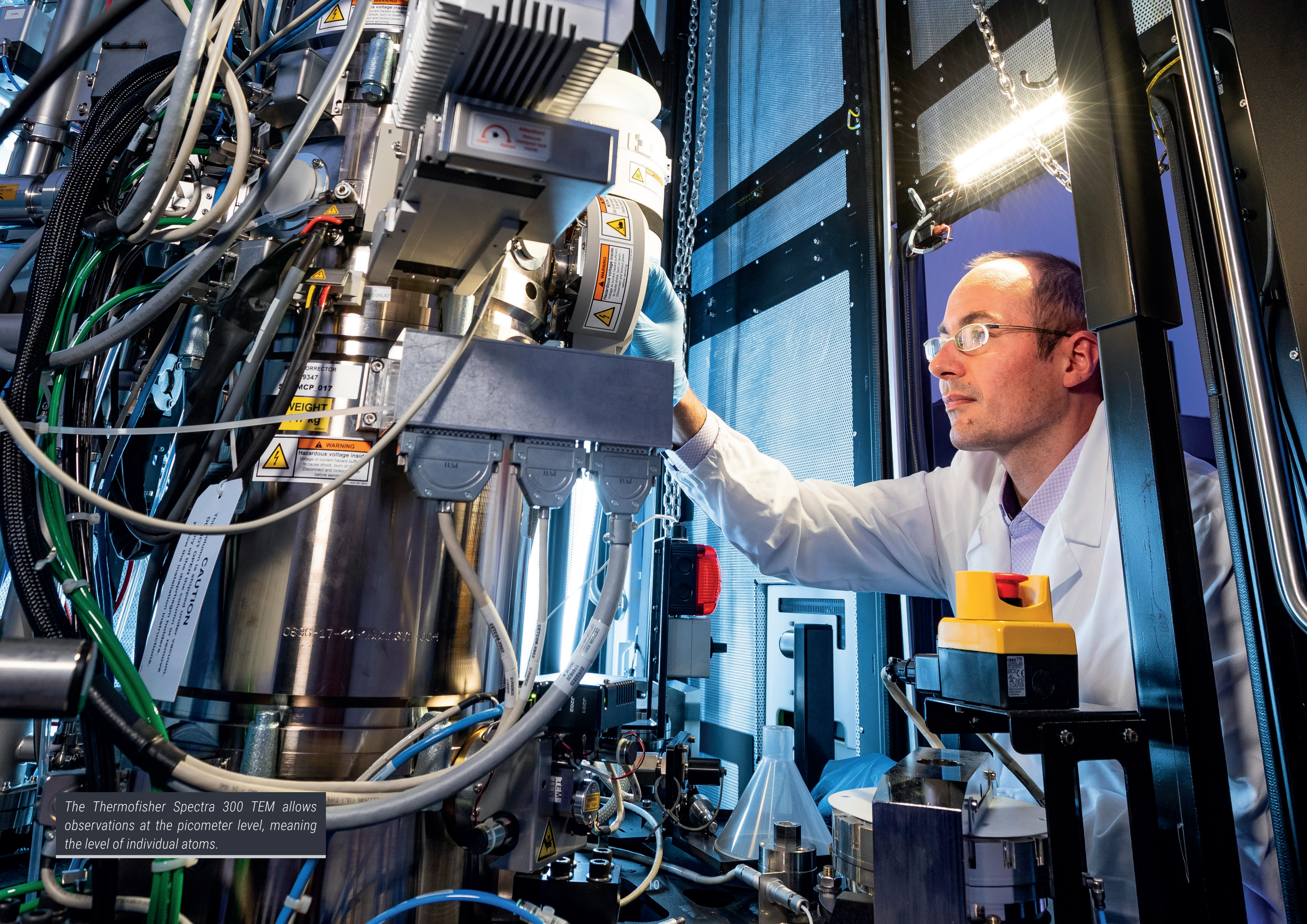
The relatively young average age of IIT researchers is a testament to the Institute's ability to attract emerging talents.

An infrastructural overhaul of about EUR 50 M is planned in order to increase the level of automation and data management in the main laboratories and to guarantee state-of-the-art instruments. Part of the investment will increase energy efficiency in IIT's buildings as we redesign our workflows in light of our increased reliance on AI, automation, robotics, and further interdisciplinarity.

The total investment of this Strategic Plan is slightly above EUR 1 billion in six years. The total direct allocation to research is about 2/3 of the budget, with 25% allocated to support and infrastructure, and less than 10% to governance and administration.

As we mentioned earlier, the Blue Sky Research program receives about 1/3 of the total research effort. AI and digital receive more than EUR 150 million (~20% of the total research effort) demonstrating the size of the planned change in our approach to science and education. Technology transfer is also receiving a greater share of the budget to guarantee greater momentum.

The expected acceleration of results – due to the "AI first" approach – will be gauged by an increased rate of scientific discovery, further stable and valuable industrial relationships, and increased quality of training.



The Thermofisher Spectra 300 TEM allows observations at the picometer level, meaning the level of individual atoms.

The Mission

The Italian Institute of Technology (IIT) articulates its statutory mission in three main components, that is:

- **Research mission**: to carry out excellent science and develop cutting-edge technology;
- **Technology transfer mission**: to apply technology in order to play a strategic role in the competitiveness of the Italian production system;
- **Higher education mission**: to implement programs dedicated to highly specialized training and education.

These elements of our mission are tightly connected. Research generates our intellectual property, which feeds into technology transfer through either industrial exploitation or healthcare applications.

It is therefore important to guarantee a large body of high-quality research output, since what reaches the market is only a fraction of the total research output.

We train students and postdocs not only to help them bring innovation to industry but also because a continuous influx of diverse minds is the key ingredient of a creative research environment.

Societal impact

Our research will positively impact the two major challenges of the 21st century, namely, care for the environment (Earthcare) and care for human health (Healthcare).

Earthcare and Healthcare are areas where technical solutions may have large societal impacts. They also represent large markets and, as such, they provide a vast swathe of opportunities for technology transfer[1,2].

Given the excellent results of IIT's Sustainability Initiative, our researchers are well-positioned to deliver in the sustainability sector with a considerable share of nanomaterials, biomaterials, recycling, process engineering, and robotics. Research on photovoltaics and printable organic electronics directly contributes to our sustainability endeavor.

Thanks to recent infrastructural investment, 31 ERC grants, half of IIT's current ERC portfolio, and the NextGenEU/PNRR program, our contribution to the field is both substantial and credible.

IIT research can also deliver robustly in the healthcare domain. For example, our RNA Initiative has already demonstrated its ability to deliver concrete solutions, having spun off the CMP^{3}VdA project in Valle d'Aosta[3], which applies bioinformatics and machine learning methods to computational and medical genomics for oncological and neurological patients.

In parallel, we used digital simulation and in silico engineering to design interventions for neurodevelopmental diseases[4]. Several of IIT's Principal Investigators (PIs) are actively developing technologies for neuro-oncological diseases and disorders.

1 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

2 https://www.economist.com/business/2018/10/13/minds-do-matter.

3 The CMP3VdA – 5000 genomes project aims to develop precision medicine workflows for several pathologies. It is carried out in collaboration with several institutional partners and companies in the northern Italian region of Valle d'Aosta.

4 A class of molecules designed digitally to help balance Cl- ions in neurons. A startup company, Iama Therapeutics, was launched in 2022.

Investment

1. **Sustainability Initiative**: budget EUR 8 M/year, 34 Research Units & Facilities, 60 researchers, ~EUR 24 M/year of EU projects and NextGenEU/PNRR
2. **RNA Initiative**: budget EUR 5 M/year, 21 Research Units and Facilities, more than 45 researchers, ~EUR 9 M/year of EU projects and NextGenEU/PNRR

Environmental monitoring is one application of bioinspired robotics.

Assessing the past and present

IIT Strategic Plan 2018-2023 reflects our overarching priority of developing Human-Centered Science and Technology with an approach that is not merely multidisciplinary, but rather merges different skills and expertise into a truly interdisciplinary synthesis.

Interdisciplinarity means breaking the barriers between fields to build common ground[5]. The elimination of discipline-to-discipline boundaries is a prominent feature of IIT's research environment, which will be continued in this new Strategic Plan.

Main achievements

Description	Result	Importance
Increasing competitive funds	EUR 26.6 M in 2018, EUR 43 M in 2021, EUR 79.5 M[6] at end of 2023, NextGenEU ~EUR 120 M (2023-2026)	HIGH
Leadership in Artificial Intelligence (AI)	IIT becomes the first Italian node of the ELLIS[7] network	LOW
	Spoke Leader of FAIR, the NextGenEU partnership on AI (~EUR 4 M budget)	MEDIUM
Leadership in HPC and Quantum Computation	IIT is Spoke Leader of the National Center on HPC & QC (a EUR 320 M project)	MEDIUM
	IIT budget is EUR 7.9 M	LOW
Growing industrial sponsorships (SRAs) and licensing	Cumulative number of industrial contracts (licensing excluded): 2018 = 517, 2021 = 723, 2023 = 827	HIGH
	Cumulative number of licensing and option agreements: 2018 = 45, 2021 = 94, 2023 = 126	HIGH
Increasing number of patents	Number of patent families: 2018 = 249, 2023 = 424 (cost per patent family -55%)	MEDIUM
Growing entrepreneurship	Number of startups: 2018 = 18, 2021 = 28, 2023 = 34	HIGH

5 Mind meld. Nature 525, 289–290 (17 September 2015) doi:10.10386/525289b.
6 EUR 51 M from NextGenEU/PNRR and the National Plan for Complementary Investment to NextGenEU (PNC) projects.
7 http://www.ellis.eu.

Further relevant facts

Description	Result	Importance
Nurturing startup ideas: the RoboIT network	IIT becomes the Hub of a network of technology transfer initiatives launched by CDP Venture – the VC branch of the Italian Sovereign investment fund. Operations began in 2022. A startup accelerator located in Genoa is in the making, financed by CDP and the Ligurian Regional public investment company (Filse)	MEDIUM
A fully fledged startup accelerator: IIT[4]	The IIT[4] accelerator program received a strong boost from the NextGenEU/PNRR program as part of the Innovation Ecosystem of Regione Liguria with a budget of EUR 109 M	MEDIUM
IIT's startup incubator	IIT's startup incubator was inaugurated in 2023	MEDIUM
Prof. Cavalli appointed director of CECAM for four years	An important recognition for IIT's research quality. CECAM is the leading society bringing together the best of class in atomistic and molecular simulations	MEDIUM

Still in the making

Aspirations	Target value (yet to achieved)	Urgency
PhD School	The area of higher education requires further organizational improvement. A PI has been appointed to the role of Associate Director for Higher Education, and a new office (designed in 2023) will incorporate the PhD school's themes, mentoring and career building, thus unifying all of IIT's higher education activities	HIGH
More focus on our young researchers: a mentoring program @IIT	Mentoring is crucial to building a career path for the young scientists that approach IIT for a PhD or postdoc.It will be incorporated into the Higher Education office ("People and Higher Education" on page 42)	HIGH
Increase internationalization	Expand the geographical distribution of foreign students and collaborators to include North America, Northern Europe, Japan, Korea, and Australia, which are currently underrepresented	MEDIUM

Scientific and Technological leadership

IIT's PIs have received several awards, prizes, and special recognitions that testify to their position in the international scientific community.

Awardee	Award
Michele Parrinello	Aneesur Rahman Prize for Computational Physics (1995), Berni Alder CECAM Prize in Computational Physics (2010), Benjamin Franklin Medal in Chemistry (2020), The European Chemistry Gold Medal (2020), Giulio Natta Medal (2021)
Sauro Succi	Aneesur Rahman Prize for Computational Physics (2017), Sigillum Magnum from the University of Bologna (2018), Berni Alder CECAM Prize in Computational Physics (2019), Honorary Professor at the University College in London (2022)
Giancarlo Ruocco	Cozzarelli Prize, Applied Physics Class (best paper on PNAS of the year 2021), Elected member of the European Academy (2022)
Liberato Manna	Highly Cited Researcher (Clarivate Analytics) 2018, 2019, 2020, 2021, 2022, Fellow of the Royal Society of Chemistry (2017)
Mike V. Lombardo	Highly Cited Researcher (Clarivate Analytics) 2021, 2022
Annamaria Petrozza	Highly Cited Researcher (Clarivate Analytics) 2018, 2019, 2020, 2021, Fellow of the Royal Society of Engineering (2015)
Andrea Cavalli	Appointed as Director of the European Center for Atomistic and Molecular Computation (2023-2026)
Agnieszka Wykowska	Delegate to the European Research Area (ERA) Forum, EU Commission (2022)
Arash Ajoudani	IEEE RAS Early Academic Career Award in Robotics and Automation (2021)
Antonio Bicchi	IEEE RAS George Saridis Leadership Award in Robotics and Automation (2018)
Natale L., Metta G., Ajoudani A., et.al.	KUKA Innovation Award 2018 Winner
Raffaella Tonini	Aspen Institute Italia Prize for the scientific collaboration between Italy and US (2023)
Irene Bozzoni	Member of the Scientific Committee of the Armenise-Harvard Foundation (2018), the Board of the Scuola Normale di Pisa (2022), the Scientific Advisory Committee of the European Molecular Biology Lab (2020)
Alberto Diaspro	Gregorio Weber Award for Excellence in Fluorescence Theory and Applications (2022)
Fabio Benfenati	Representing Italy in the Council of Scientists of the Human Frontiers Science Program (2023)

Completion of IIT's infrastructure

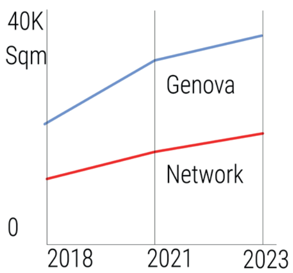
IIT's infrastructure was expanded between 2018 and 2023. In completing the central laboratories in Genoa, the most important milestones were:

- The CHT (Erzelli, about 8000 m²): inaugurated in 2019;
- The CRIS (San Quirico, 10,000 m²): completed and inaugurated in 2022;
- Additional expansion, on a per-need basis, at the Business Incubation Center (BIC, about 1500 m²) in west Genoa (close to other IIT buildings): started in 2022 (expected 2024);
- The H_4E incubator on the 11th floor of CHT (about 1500 m²): inaugurated 2023;
- NSYN at IRCCS San Martino-IST in Genoa will host two PIs (under negotiation): expected in 2024.

With the same goal, IIT has acquired and prepared new laboratories and office space in:

- CNST in Milan (formerly @Polimi): doubled laboratory size in a new building with financial support of EUR 2 M from Regione Lombardia;
- CNCS in Trento: the new laboratories at the CIMEC Center in Rovereto are now up and running, a new PI joined the Center in 2023.

IIT's new laboratories host important shared Facilities – our technological platform – such as genomics, HPC & data storage, electron and optical microscopy, chemistry, mechanical and electronic fabrication.



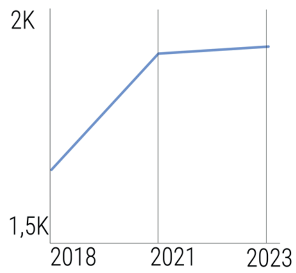


Figure 1: The increased size of laboratories and offices (left panel) compared to the increased number of staff at IIT (right panel).

Figure 2: IIT's Central Research Laboratories in Genoa and the location of the Network Centers.

Tableau de bord

The growth of IIT (2018-2023)

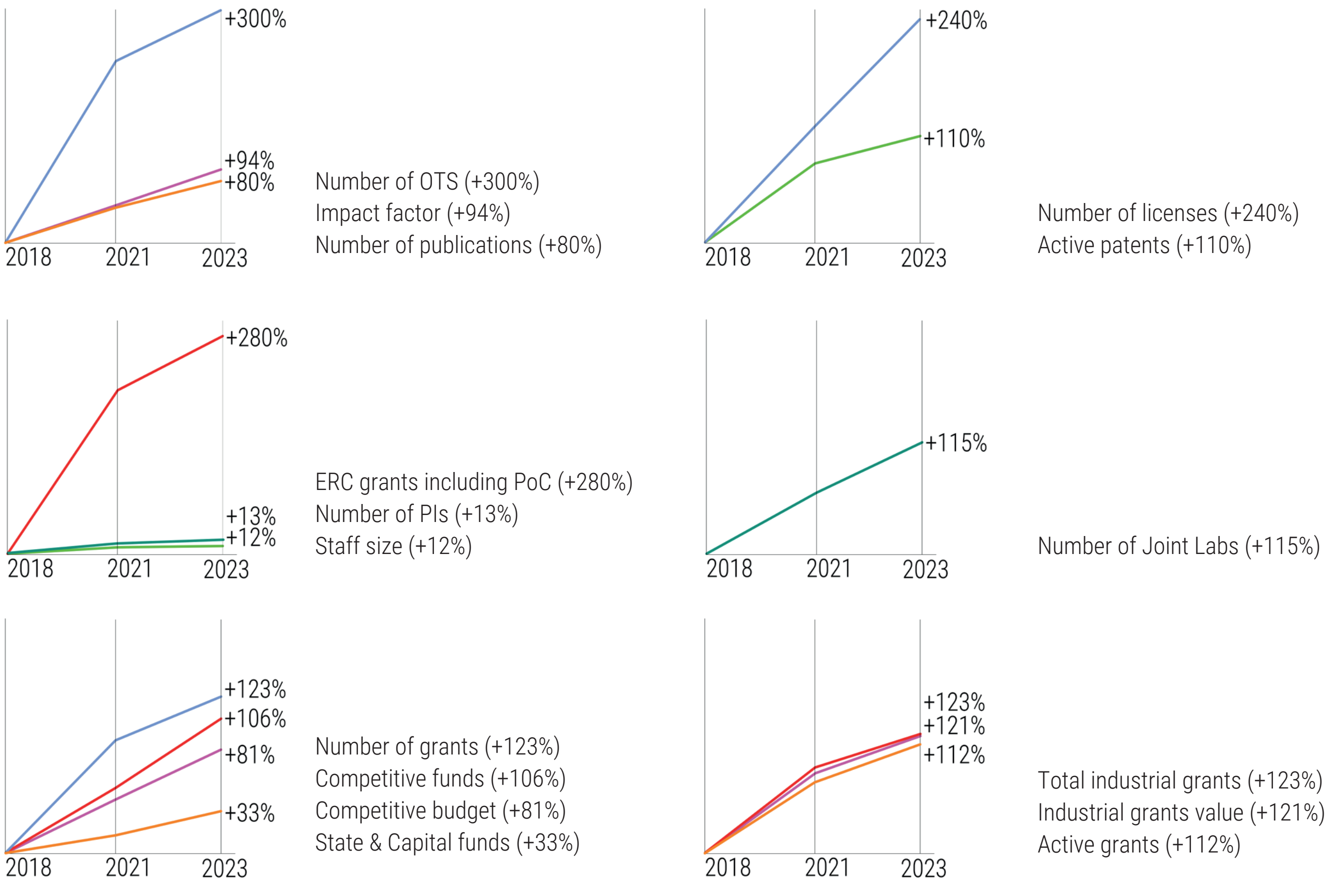


Figure 3: Illustrating IIT's growth in 2018-2023. Left: IIT's research output (ERC vs. PIs is highly favorable, about 50% of the PIs are ERC grantees), funding from competitive projects has increased despite the slightly decreasing State budget, the dissemination output (ß) has also increased considerably. Right: technology transfer output is growing steadily in the number of patents, licenses, industrial contracts and Joint Laboratories. Increments are in percentage of the baseline measured on January 2018.

Technology transfer data (ASTP Survey)

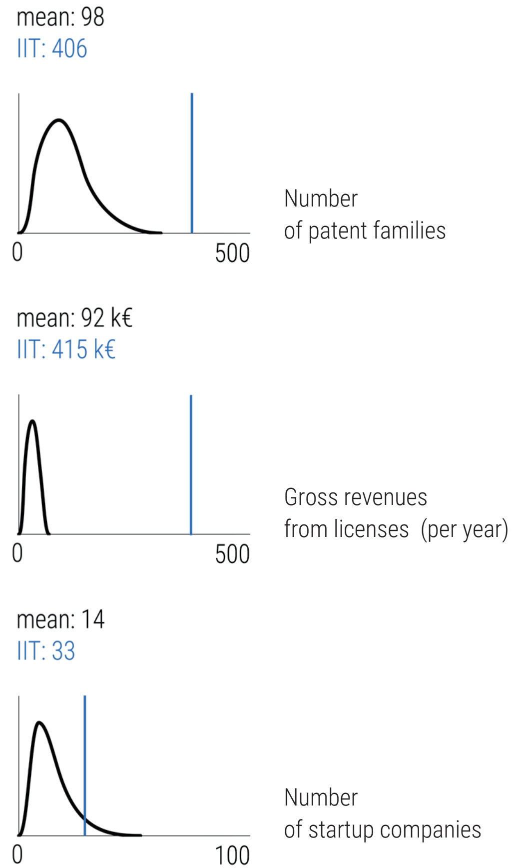


Figure 4: Technology Transfer Data. Compared to 500 technology transfer offices across Europe. The distribution of values of the 500 surveyed offices is shown as a Poisson distribution. IIT's score is represented by the vertical bar.

Interpreting and measuring scientific output

Due to growing concern about the current methods of evaluating science and scientific impact, IIT signed the global Agreement of the Coalition for Advancing Research Assessment (CoARA[8]). The CoARA Agreement was drafted by the European University Association and Science Europe with the support of the EU Commission, funding agencies like the ERC, research institutes and organizations[9], and researchers themselves. According to CoARA, the process of peer review is central to evaluating research results. Peer review should involve sufficient time, effort, and depth dedicated to the qualitative evaluation, rather than reliance on proxies, such as numerical Key Performance Indicators (KPIs).

Certified data source (see page 18)

Our tableau de bord summarizes two sources of data:

1. The internal IIT databases including indicators of budget, value of projects, number of people, patents, and industrial grants, as well as the impact on the media
2. Technology transfer data, extracted from the most recent ASTP survey (2021), which includes data from more than 500 technology transfer offices in Europe

The Chemistry Facility allows IIT's Research Units to develop synthesis routes for the production of inorganic or hybrid (organic/inorganic) materials and, in particular, nanoscale objects.

8 The EU and member countries are challenging and eschewing the use of numerical and merely quantitative indicators (www.coara.eu).

9 https://www.nature.com/articles/d41586-022-02037-8.

Our vision for a new Strategic Plan

The world of science and innovation is undergoing a paradigm change.

Scientists now use data to train models that can predict the 3D shape of proteins, understand how to synthesize new chemical compounds, optimize the structure and shape of robots, bridges, and airplanes, or spot mutations in the genome. We can simulate with high accuracy how candidate drugs will bind to a given pocket in a protein, greatly accelerating the discovery of new drugs.

Computational methods and, in particular, artificial intelligence (AI) are prompting radical changes in how scientific experiments are designed and new technology is developed.

IIT has a longstanding tradition of embodied AI research, epitomized by the iCub[10] project. For robotics, the iCub is the launchpad for jumpstarting further applications of AI to our experimental research activities. The Brain and Machines Flagship Program (see "The Flagships Programs" on page 34) leverages this consolidated strength.

To optimally exploit AI in science and technology, IIT must pivot its current research model.

Opportunities for AI (Italy)

1. **Counteract** negative demographic trends (-3.7 M workers) in the population and workforce
2. **Increase value added** by the workforce by 18% on average
3. **Reduce cost** of industrial processes and/or save time (work hours per task)

To pivot, IIT will invest in changing its culture to ensure that data is AI-ready. It is not enough to store raw data. Rather, in line with the FAIR guidelines, data must be Findable, Accessible, Interoperable, and Reusable.

These guidelines emphasize machine actionability and therefore the use of data by AI methods. IIT has accumulated a rich body of data from its experimental studies, which may form the training sets for further machine learning studies. This in turn may help us develop new and improved algorithms. Hence, IIT will invest in infrastructure that supports the conservation and processing of data in its specific research areas, i.e. robotics, nanomaterials, neuroscience, genomics, and computational physics.

IIT has already made key infrastructural investments in high-performance computing (HPC, 3Pflops in 2023) and storage (10PB), which are fully available to IIT's researchers.

We will add laboratory automation, integration of AI software into the design of experiments, direct metadata production, and software pipelines. IIT can leverage its participation in the National Center on HPC and Quantum Computing, which is funded under the umbrella of the NextGenEU/PNRR program. The National Center will contribute in part to the software development.

Computational tools developed for science are often released under open source licensing and/or as online/cloud versions that can be accessed under institutional/educational agreements for a reasonable fee. AI is thus becoming a part of every scientist's toolbox.

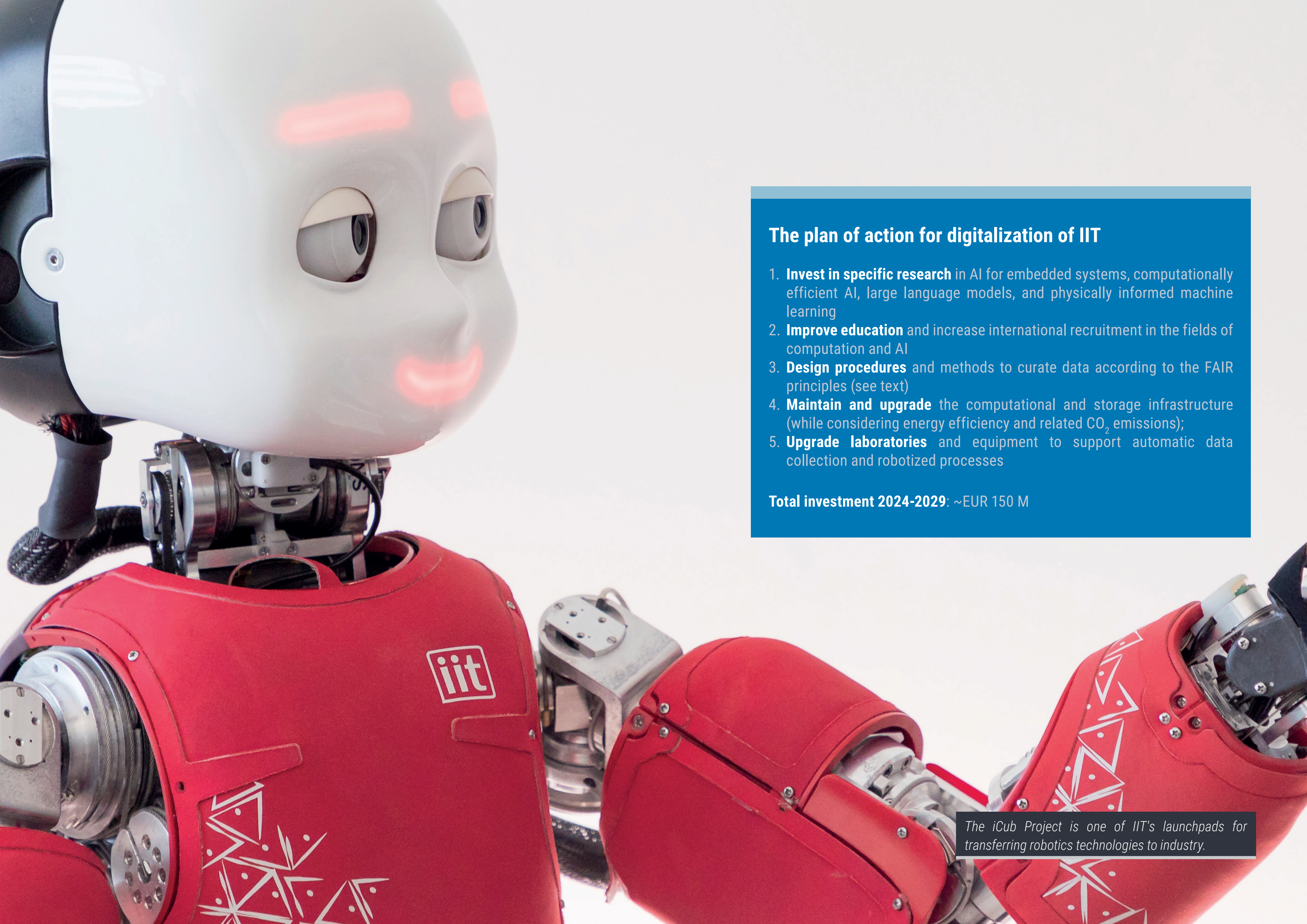
Data and AI are not sufficient. Human talent is needed to drive research and innovation by asking new and challenging questions. Thus, to complete its digital transition, IIT will robustly invest in education and recruitment in the fields of computation and AI. Data science must become part of the training of all researchers, with a special focus on upcoming generations. Higher education in data sciences receives funding from the NextGenEU extended partnership on AI (named FAIR). Our participation in the ELLIS European Network on machine learning is another strength.

Additionally, IIT will invest in the creation of new Research Units to conduct research in basic and applied AI. To compete at a global level in computation, IIT's strategy is to hire young people and train them to excel. We have demonstrated the capacity to do so: IIT's alumni have secured prestigious positions worldwide, including MIT, DeepMind, Google, and UCL, to name a few.

Although it is difficult to compete with large corporations in designing large language models (LLMs), there is room for human ingenuity in reducing the computational cost of machine learning methods, as demonstrated by some of our past work.

To this end, we will investigate the low data regimes of machine learning as well as the new trend of physically informed machine learning in the context of embodied models (robotically embodied) and computational chemistry. Existing open-source models will help us to experiment with LLMs and build applications in support of IIT's science.

10 http://www.icub.org.



The plan of action for digitalization of IIT

1. **Invest in specific research** in AI for embedded systems, computationally efficient AI, large language models, and physically informed machine learning
2. **Improve education** and increase international recruitment in the fields of computation and AI
3. **Design procedures** and methods to curate data according to the FAIR principles (see text)
4. **Maintain and upgrade** the computational and storage infrastructure (while considering energy efficiency and related CO_2 emissions);
5. **Upgrade laboratories** and equipment to support automatic data collection and robotized processes

Total investment 2024-2029: ~EUR 150 M

The iCub Project is one of IIT's launchpads for transferring robotics technologies to industry.

The organization of research

IIT comprises about 80 Research Units, each headed by an independent Principal Investigator (PI) and comprising a research team, laboratory space, and equipment.

Research Units are grouped in four broad Research Domains (RDs), that is: Robotics, Nanomaterials, LifeTech, and Computational Sciences.

Each RD is coordinated by an Associate Director who guarantees coherent development by monitoring the evolution of the international research landscape, participating in the relevant international research bodies, encouraging exploitation of IIT's technology, and monitoring competitive and industrial funding opportunities. However, this is not a hierarchical structure as PIs enjoy substantial academic freedom.

PIs in the same RD share technical expertise, technologies, equipment, and, broadly speaking, they are part of the same scientific community. Grouping Units in RDs simplifies the gauging of IIT's position in the international research landscape and the comparison of Research Units.

The new Strategic Plan heralds major changes: in addition to the RDs and the large packet of curiosity-driven Blue Sky research activities, the Plan defines five goal-oriented (multidisciplinary) Flagship Programs that span RDs. IIT's research will decisively shift towards greater transversality.

While Blue Sky Research pursues unexplored cutting-edge science and technology, the Flagship Programs favor project-oriented management with strong goal-driven engineering to increase the volume of technology transfer and nurture new interdomain ideas.

IIT will commit specific financial resources to the following Flagship Programs:

- Technologies for Sustainability;
- Brain and Machines;
- RNA Technologies;
- Teaching Science to Computers[11] ;
- Technologies for Healthy Living.

11 Core machine learning and AI is part of this Flagship Program (although AI is not in the title).

The Flagship Programs are managed by one PI (or more) who coordinates the high-level day-to-day activities with an approach similar to the coordination of multipartner EU projects. The coordinators of the Programs and the Associate Directors collaborate to guarantee the overall consistency of IIT's research.

The total size of the financial plan from 2024 to 2029 is estimated to be slightly above EUR 1 B. The allocation to direct research costs is about EUR 730 M, with EUR 229 M allocated to infrastructure, including EUR 43 M for utilities. Administration, governance, and control are allocated about EUR 14 M per year for a total of EUR 85 M. These figures include the yearly State funding, the capital funds allocated to specific programs (such as infrastructural improvement and energy efficiency), competitive and industrial funds, as well as NextGenEU/PNRR that totals about EUR 120 M.

Curiosity-driven Blue Sky Research activities amount to about 1/3 of the EUR 730 M research funds. The Flagship Programs' size is proportional to the contribution of each PI and their respective Units. A special fund has been earmarked to support intra-Flagship collaborative work. In terms of size, the Technologies for Sustainability Program and the Brain and Machines Program share 36% of the total research budget, the RNA Technologies amounts to 11%, and the Technologies for Healthy Living Program and Teaching Science to Computers Program about 9% each.

The Computational Sciences RD will receive a 4% greater share of the total budget, reducing the comparative investment in other RDs.

SOCIETAL CHALLENGES: SUSTAINABILITY, HEALTHCARE

		RESEARCH DOMAINS			
		Robotics	Nanomaterials	Life Technologies	Computational Sciences
CURIOSITY DRIVEN RESEARCH	Blue-sky	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH
FLAGSHIP PROGRAMS	Technologies for Sustainability	HIGH	VERY HIGH	MEDIUM	MEDIUM
	Brain and Machines	MEDIUM	LOW	VERY HIGH	MEDIUM
	Teaching Science to Computers	MEDIUM	MEDIUM	MEDIUM	VERY HIGH
	RNA Tech	LOW	MEDIUM	VERY HIGH	MEDIUM
	Technologies for Healthy Living	VERY HIGH	MEDIUM	MEDIUM	MEDIUM

The Strategic Plan matrix architecture. The scientific and intellectual contribution of each RD to the Flagship Programs is shown as shades of blue.

	Total Budget per Program (in million Euro)	RESEARCH DOMAINS				
		Robotics	Nanomaterials	Life Technologies	Computational Sciences	Total
CURIOSITY DRIVEN RESEARCH	Blue-sky	73	68	73	37	251
FLAGSHIP PROGRAMS	Technologies for Sustainability	38	36	38	19	132
	Brain and Machines	39	37	39	20	134
	Teaching Science to Computers	16	15	16	8	55
	RNA Tech	25	24	25	13	87
	Technologies for Healthy Living	21	20	21	11	72
	Total	**212**	**199**	**213**	**107**	**731**

The estimated budget (in EUR M) calculated for the entire duration of the Plan for each RD (columns) and Program (rows). Totals show the allocation to research (infrastructure costs not shown).

	FTE per Program per Year	RESEARCH DOMAINS				
		Robotics	Nanomaterials	Life Technologies	Computational Sciences	Total
CURIOSITY DRIVEN RESEARCH	Blue-sky	172	162	173	87	594
FLAGSHIP PROGRAMS	Technologies for Sustainability	90	85	91	46	312
	Brain and Machines	92	87	93	47	318
	Teaching Science to Computers	38	35	38	19	130
	RNA Tech	69	56	60	30	206
	Technologies for Healthy Living	50	47	50	25	171
	Total	**502**	**471**	**504**	**255**	**1.732**

The estimated full-time equivalent per year (averaged) for each RD (columns) and Program (rows). The total shows that the number of staff members is estimated to grow only moderately (PhD students are not included).

Robotics

Robotics researchers design a variety of robots in hardware and software that are engineered to work on factory floors, in homes, or in hospitals. Control theory, electronics, artificial intelligence (AI), psychology, and cognitive neuroscience are some of the disciplines that contribute to IIT's robotics research.

In terms of value, the robotics market has a 1:2 ratio of industrial to service robots. Collaborative robots are on the rise but comprise less than 10% of the total value of the market. There is a clear trend towards service robots (compound annual growth rate of 7%) and interactive robots, which shows that research in this field (including with AI) is percolating into the market. The relative share of medical robots is in the billion euros range and is expected to double in the next few years (see "Technologies for Healthy Living" on page 60).

Strengths

Engineering skills (mechanics, electronics, control design, real-time software)

Deep knowledge of the electric motor actuation train

Locomotion and humanoid robotics – a uniquely strong feature of IIT's robotics

Human-robot interaction and embodied AI

Bio-inspired approach and closeness with brain science

Weaknesses

Relatively narrow range of technologies (e.g. electric)

Thinning connection between embodied AI and the study of cognitive neuroscience

Relatively small traditional industrial robotics (missed opportunity)

Lack of unitary (large) programs in robotics

Opportunities

Space robotics

Robotics for healthcare

Assistive robotics

Emerging paradigms (soft robotics)

More industrial applications

Threats

Obsolescence of technology

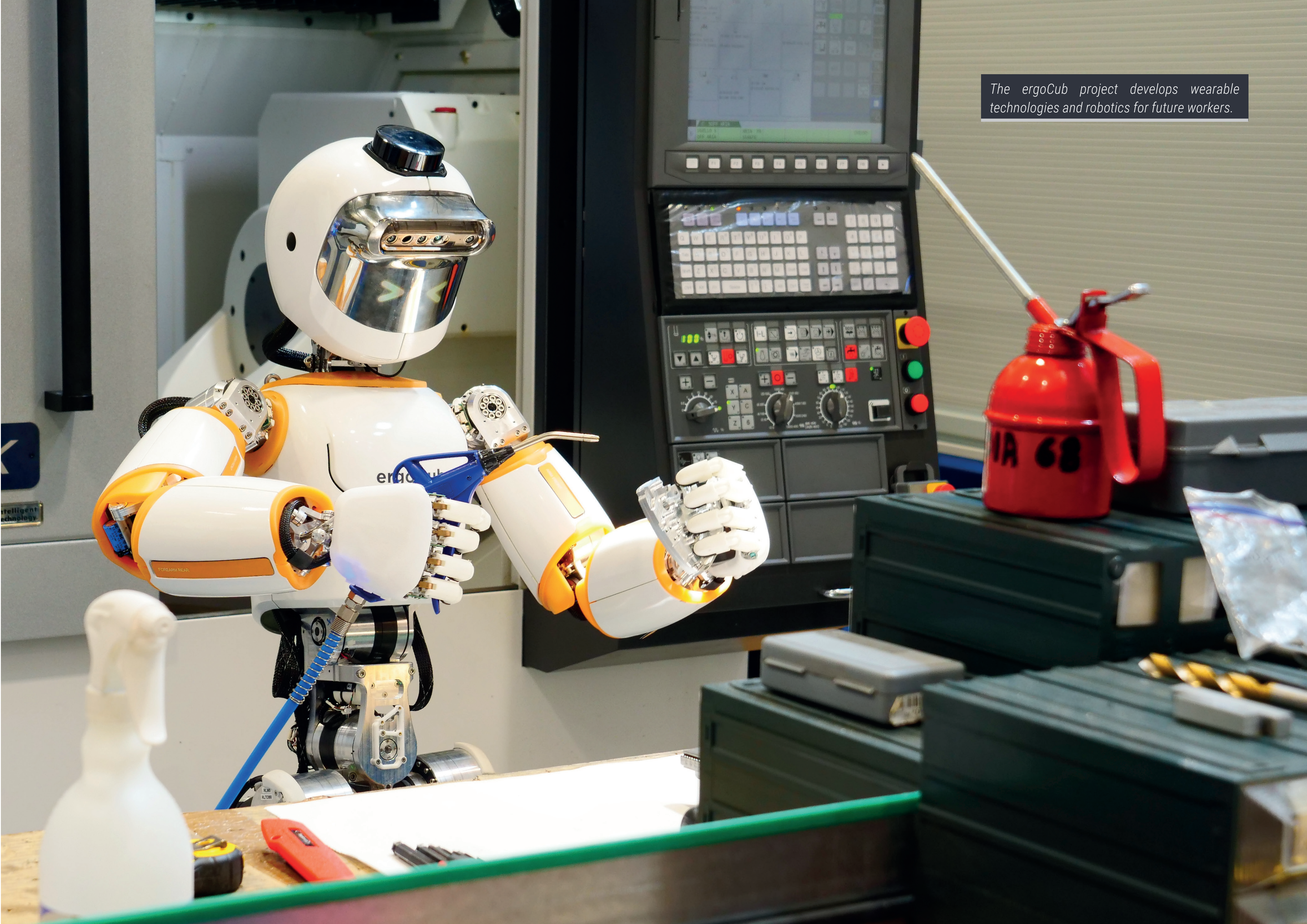
Strong competition from industrial players (Boston Dynamics, DeepMind, Tesla, Toyota)

Limited size of Italian industrial players

Action plan

To capitalize on our strengths and market opportunities, IIT will:

- Further invest in and promote Blue Sky Research in robotics such as i) soft robotics, ii) human-robot interaction, iii) bio-inspired approaches, iv) space robotics;
- Invest in linking neuroscience to robotics to advance embodied AI (see "Brain and Machines" on page 54);
- Invest in the technological platform and especially in humanoid robot design. Europe has a limited number of players: IIT, DLR, and ETH (investment is rising outside of Europe);
- Invest in maintaining a technological edge (e.g. electronics, new motor technology), including via industrial partnerships (e.g. chip design);
- Promote the development of medical robotics technology such as i) prostheses, ii) exoskeletons, iii) surgical & medical robotics, iv) assistive robotics for healthcare/elder care.



The ergoCub project develops wearable technologies and robotics for future workers.

Nanomaterials

Nanomaterials researchers leverage IIT's long tradition of advanced chemistry, physics, and engineering to design new materials for the growing needs of sustainable development. We target several application areas including energy and healthcare. We design bespoke materials with the aim of finetuning their mechanical, optical, thermal, or electrical properties.

The nanomaterials market is enormous. Given the range of applications associated with implementing the energy transition, sustainability, and environmental preservation, the market size is estimated at several trillion euros per year (for example, the renewable energy sector alone is projected to be worth about EUR 2 T in 2025). The bioplastics market is forecasted to reach about EUR 15 B in 2028, an increase of more than 100% with respect to 2021.

Strengths

Theory and engineering skills

Computational component of materials simulation

Core application domain of sustainability and energy – technology transfer potential

Application to medicine and to healthcare in general

Unique set of advanced equipment, at least at the European level

Weaknesses

Expensive maintenance and upgrade of the core equipment in materials science

Lack of computational components for device design and materials application

Lack of specific focus on catalysis and spectroscopy (missing critical mass)

Effect of fractionation of the Facilities vs. PIs' laboratories may weaken knowledge sharing

Opportunities

Large market pull in the energy sector (production, storage, transmission)

Very good opportunities for technology transfer and direct sponsored research agreements

Tapping into the growing trends of automated laboratories for material development (robotized)

Great opportunity to use AI to model, discover, and validate materials in applications in Robotics and LifeTech

Threats

Maintaining momentum in investing in equipment and optimization of the laboratories

Strong competition from industrial players in areas that are relatively mature

Obtaining suitable paths to technology transfer of medical nanomaterials or materials for the study and preservation of cultural heritage

Action plan

Given the current strengths and weaknesses of the Nanomaterials RD, we plan to

- Invest in 1) a new robot-driven chemistry laboratory, and 2) renewing a good proportion of the existing infrastructure;
- Complete the expansion of the energy sector and consolidate the link between CCT (Genoa/Morego) and CSFT (Turin);
- Expand the areas of catalysis and spectroscopy via targeted hiring at the Senior Researcher or PI level;
- Expand the interaction between materials science and sustainability/energy/photonics applications;
- Further invest in the computational components of materials science and digitally supported device design (see also the Flagship Program "Teaching Science to Computers" on page 58);
- Further invest in the development of new materials for robotics and in the concept of green robots (see the Flagship Program "Technologies for Sustainability" on page 52).

We valorize waste and take inspiration from nature to produce solutions for sustainable living and development.

Technologies for Life Science (LifeTech)

The Technologies for Life Science researchers pursue the development of technology with two major focuses: molecular biology of RNA and neuroscience. The LifeTech Research Domain (RD) uses computational and AI methods extensively, for example, to engineer molecules that modulate a cell's biochemical processes with high specificity, or in medical genomics for personalized medicine. Additional topics are robotics for healthcare, and smart devices for drug delivery.

The technologies for life science market is growing steadily owing to the increasing age of the world population. Since 2012, global sales of biotechnology drugs (including mRNA drugs) have quadrupled. This trend accelerated in 2021 and 2022 due to the SARS-CoV-2 pandemic. Another sign of this biotechnology boom is the increasing value of closely related markets such as precision medicine (30% share of all newly approved FDA drugs), gene cloning, and nucleic acid purification. Neuroscience is also of the utmost importance. Neurodevelopmental disorders and neuropsychiatric and neurodegenerative diseases affect large sections of the population with a severe societal burden[12].

Strengths

World-class expertise on noncoding RNA and genomics

Broad, multiscale, and multimodal experimental neuroscience

Small but rich network of clinical partners including the CMP³@VdA laboratory in Aosta

Excellent results in technology transfer (e.g. drug discovery for brain diseases)

Cutting-edge computational methods in bioinformatics

Weaknesses

Insufficient critical mass of computational neuroscience

Fragmentation and consequent lack of critical mass at specific locations

Low diversity (nationality of researchers)

Quality of the research output is not uniform across the RD

Opportunities

The Erzelli hospital flagship project may become a game changer for IIT's ambitions in 1) neuroscience, 2) genomics, and 3) medical robotics

The digitalization of the Italian healthcare system offers many opportunities for applications of IIT's technology

Synthetic biology (engineering cell processes to give organisms new properties)

Threats

Obtaining suitable paths to technology transfer of medical solutions (e.g. RNA-based)

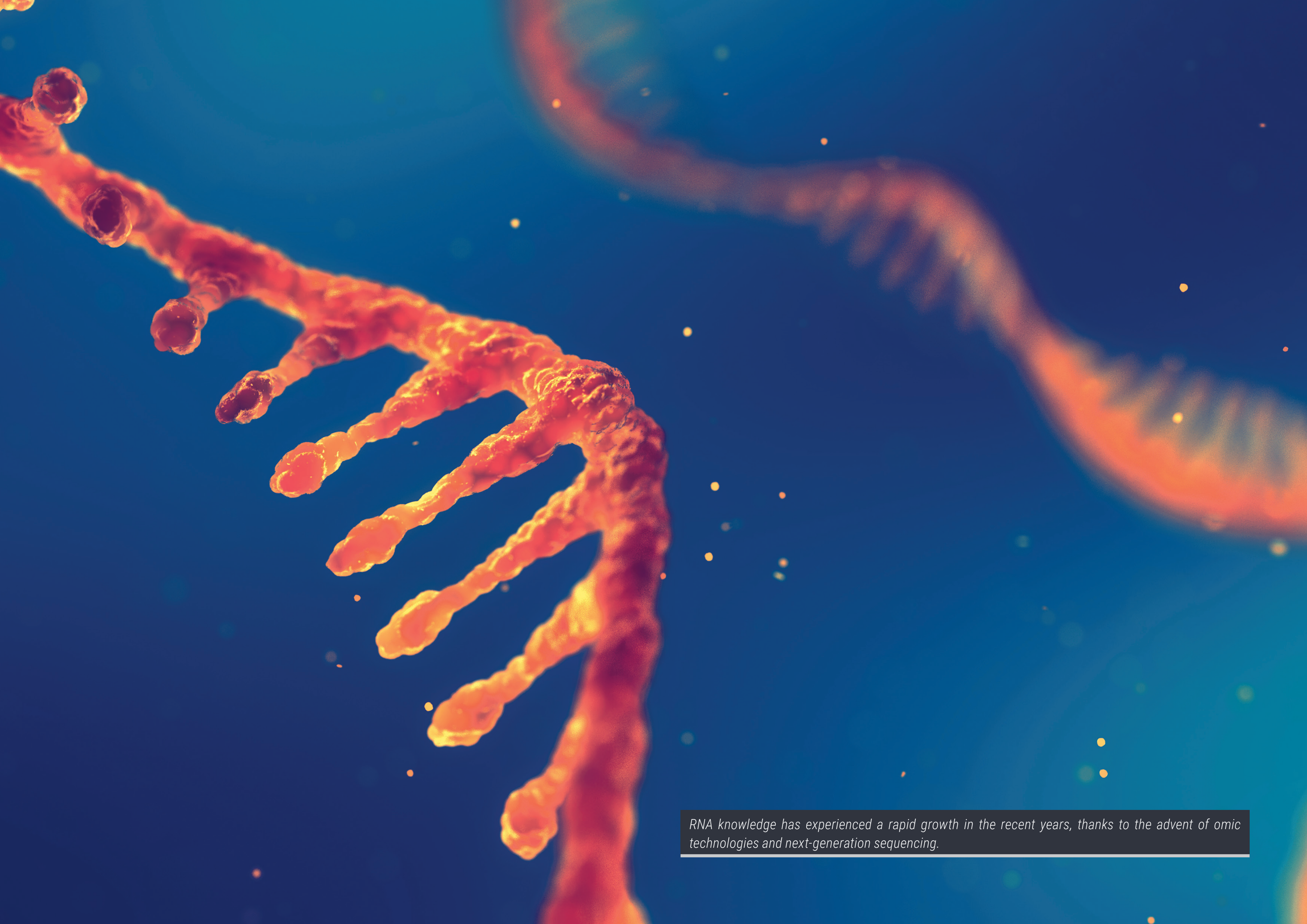
Resources required for clinical translation may not be feasible for IIT

Action plan

Given the assessment of the LifeTech RD, we plan to:

- Continue the expansion of the RNA Flagship Program by investing in young international scientists;
- Invest in the continuation of the precision medicine program (both the CMP³@VdA and the CHT project in Genoa);
- Expand neuroscience by creating stronger links with other disciplines (see the Flagship Program "Brain and Machines" on page 54);
- Invest in computational neuroscience and synthetic biology.

12 https://www.who.int/news-room/fact-sheets/detail/mental-disorders.



RNA knowledge has experienced a rapid growth in the recent years, thanks to the advent of omic technologies and next-generation sequencing.

Computational Sciences

Computational Sciences researchers focus on computational chemistry and physics, AI (particularly computer vision and machine learning), and the hardware that supports high-performance computing (HPC). Computational chemistry and physics accelerate the discovery of new drugs, but also allow the *in silico* engineering of new materials. Our researchers develop new AI methods and mathematics to understand algorithmic performance in a variety of functioning regimes.

The computational sciences market encompasses such a wide range of technologies and applications that it is difficult to define it precisely. In science, notable examples include results obtained by large corporations such as Microsoft[13] and DeepMind[14]. They used AI to address problems in mathematics, biology, and physics. For example, automated software development (a byproduct of large language models) is expected to be worth EUR 1.5 T by 2040.

Strengths

Top-notch scientists in both atomistic and molecular simulations and the mathematics of machine learning (ML)

Extremely powerful platform of bioinformatics and engineering of new drugs

Impressive technology transfer results (e.g. drug discovery)

Tradition of developing embodied AI for robotics

Weaknesses

Critical mass of PIs in ML and AI is insufficient to compete globally

Strong investment needed to increase computational power

Opportunities

The Erzelli hospital flagship project may become a game changer for IIT’s ambitions in 1) neuroscience, 2) genomics, 3) medical robotics

The digitalization of the Italian healthcare system offers many opportunities for applications of IIT’s technology

The application of AI to IIT’s experimental science is a boon for new discoveries and technology transfer

Threats

Limited access to good pools of students/ postdocs, especially in AI/ML, due to strong competition from industry

Keeping pace with big corporations may require resources that are inaccessible to IIT (because of size/cost)

Action plan

Given the assessment of IIT’s positioning in AI and computational sciences, we plan to:

- Implement the plan for digitalization defined in the section "Our vision for a new Strategic Plan" on page 20;
- Invest in the training and acquisition of talent in all components of digital technologies;
- Create critical mass of know-how in machine learning and AI;
- Explore blue sky avenues of computation, such as non-Turing architectures, and neuromorphic brain-like architectures (see "Brain and Machines" on page 54).

13 https://www.microsoft.com/en-us/research/lab/microsoft-research-ai4science.

14 James Kirkpatrick et al. Pushing the frontiers of density functionals by solving the fractional electron problem. Science. Volume 374, Issue 6573, Dec 2021.

Advanced simulation methods have enabled the study of systems of unprecedented complexity.

Blue Sky Research@IIT

IIT's Blue Sky Research directions aim to take an ERC-like approach to scientific discovery. Stakeholders are increasingly calling for a basic science approach to scientific discovery[15] because **today's science is tomorrow's innovation**. For example, despite its focus on particle physics, CERN spun off a variety of inventions like the World Wide Web.

Blue Sky Research at IIT follows a bottom-up and exploratory approach with the sole limitation being that it should fall within one of the four Research Domains. In **Blue Sky Research, our AI-first approach is even more important** because scientific output will be boosted by the automatized exploration of new materials, generative AI solutions, and the statistical analysis and modeling of physical phenomena from large datasets.

The **Blue Sky Research** support at IIT will:

- encourage curiosity-driven research to address fundamental and innovative scientific questions;
- these questions will be driven by and be evaluated solely on excellence;
- this will lead to unexpected and serendipitous discoveries; and
- these will be the engine, often unexpectedly, of technology transfer (and frequently true technological game changers[16]).

Nurturing discoveries requires the correct mindset for science management, a solid infrastructure, and the best minds on the market.

This plan's implementation requires the three actions described in the following page.

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15 https://www.aspeninstitute.org/publications/pure-science.

16 For example, gene editing, mRNA vaccines, and the Green Fluorescent Protein.

IIT researchers can count on a network of state-of-the-art laboratories across Italy.

The plan of action for Blue Sky Research at IIT

1. **Scientific management**: evaluation processes that value discovery and assess excellence only (rather than relying on metrics, such as number of publications, impact factor of publication venues, which are a byproduct of excellent research rather than its goal)
2. **Attract the best minds on the market**: this requires meticulous work on IIT's attractiveness, internationalization, education, and further targeted investment in the best researchers. A dedicated packet will be created
3. **Maintain and upgrade the laboratory infrastructure**: great minds need the best tools to blossom. Continuous investment is necessary to allow visionary research

The Flagships Programs

The Strategic Plan recognizes the need for broader synergies to focus and deploy sufficient critical mass on selected topics. To this end, next to keeping up with Blue Sky Research, we introduce five Flagship Programs.

They aim to attack large-scale problems, which require extremely transversal skills and large collaborative teams. Flagship Programs are visionary large-scale collaborations (larger than one-to-one collaborations) across Research Units and Domains with well-defined ambitious goals. Flagship Programs aim to consolidate IIT's presence and visibility in the respective research sector.

IIT's Flagship Programs are designed to intercept:

- Societal megatrends: global warming and the aging population due to their widespread negative economic and societal impact;
- Emerging technological needs: energy transition technologies, bioengineering and healthcare, the digital transition;
- Technological trends: artificial intelligence and its subdisciplines, in particular because they can accelerate scientific discovery;
- IIT's specific strengths emerging from either Blue Sky Research or the Research Domains (RDs) as discussed earlier.

Our 80-plus Research Units (see page 70 for the definition of Research Unit) and 19 Shared Facilities collaborate in the five multidisciplinary Flagship Programs.

The goal of Technologies for Sustainability is to use our capacity to manipulate matter at various scales to create a world without pollutants. Pollutants can be plastics, heavy metals, toxic nanomaterials, flame retardants, volatile organic compounds, and greenhouse gases.

The concrete targets are to: 1) recover and valorize raw materials from waste and biomass; 2) increase the yield of conversion processes (e.g. of plastics); 3) increase the yield of catalysts in CO_2 capture and valorization (demonstrating economical sustainability); and 4) introduce sustainable materials and design in electronics, robotics, and other application fields. Computational techniques are used to analyze and model experimental data, to infer design principles of new materials, and to control robotized laboratories.

The goal of Brain and Machines is to understand how the brain processes information to generate behavior. Computational methods, specifically machine learning, will be used to model neural and cognitive processes and to embody these models in robots.

The expected outcomes are: 1) basic science: models of neural activity and behavior in perception, action, and interaction with others; 2) translational: efficient neurostimulation, rehabilitation and assistive robotics; 3) technology: new interfaces to collaborative robots for rehabilitation or operation in close contact with humans. Our ambition is to realize autonomous fully interactive, efficient, and safe robots tasked to be our assistants and companions.

The Flagship Programs are designed to intercept:

1. **Societal megatrends**: global warming and the aging population
2. **Emerging technological needs**: energy transition technologies, bioengineering and healthcare, the digital transition
3. **Technological trends**: artificial intelligence and its subdisciplines
4. **IIT's specific strengths** emerging from either Blue Sky Research or the RDs

The goal of RNA Technologies is to study RNA in order to fundamentally understand biology and so to find druggable pockets in the molecular processes of cells. Bioinformatics and computational tools in general are already the hallmark of IIT's research on RNA. Several research pipelines have been implemented and are used daily at IIT. RNA therapeutics will take advantage of the studies developed at CMP³VdA and the Joint Labs with several clinical partners as the Gaslini Children's Hospital and the San Martino Hospital in Genoa. Following our recent translational research on RNA and genomics, we expect to deliver: 1) knowledge about the regulatory mechanisms of RNA in the context of human disease, with a focus on neurodegenerative and neoplastic diseases; 2) generation of a robust IP portfolio in diagnostic and therapeutic applications; and 3) at least one RNA-based product ready for clinical experimentation, e.g. a drug candidate with preclinical validation. The ambition of the RNA Technologies Program is to drug the undruggable.

17 For example, Langevin dynamics.

Teaching Science to Computers takes an original approach to developing new methods for instilling knowledge about the laws of physics into data-driven algorithms. For example, we will study the basis of low-data regimes, continual and transfer learning, energy-efficient machine learning, computer vision, and data-driven approaches to modelling complex dynamical systems[17]. Our end-goal is to deliver artificial intelligence (AI) with computational efficiency (algorithmic cost) and guaranteed performance (bounds). Our ambition is for computational efficiency, safety, and trust to make the use of AI more democratic and open to all.

Technology for Healthy Living focuses on developing low-cost, noninvasive sensing devices to assess, in real time, the health status of a person. It will investigate technologies to remotely activate and precisely dispense therapeutics. Our concrete targets are: 1) the deployment of several sensing solutions that are embodied, for example, in the form of assistive robots; 2) the development of smart devices to deliver therapeutics; and 3) a closed-loop system that integrates measurement and on-demand intervention. Closing the loop requires data collection, patient modeling, and AI-driven analysis. We foresee a future home that takes good care of us, improving our independence and quality of life while revolutionizing caregiving and thus reducing the need to admit patients to hospital.

Materials science is a field defined by innovation and creative thinking.

Flagship Program	Aspiration	Scientific Deliverables	Technology Transfer Deliverables
Technologies for Sustainability	A zero-waste, zero-emissions, zero-hunger world, with circular materials, optimized energy efficiency, and sustainable water, soil management	Design and use of depolymerization enzymes to recover raw materials Design and use of catalysts for the energy sector Development of compostable materials from renewable sources Design and use of renewable, nontoxic materials in electronics	System for recovering clean water using engineered materials, sensors, robots, and renewable energy System for CO_2 capture and transformation and efficient photovoltaics Sustainable Internet of Things for environmental monitoring
Brain and Machines	Autonomous, fully interactive, efficient, and safe humanoid robots tasked flexibly to help us in daily life	Models of neural activity and behavior in perception, action, and interaction	New technology for neuromodulation in healthcare Rehabilitation and assistive robotics
RNA Technology	Drug the undruggable (at least in one specific neurodegenerative disease)	Knowledge about the regulatory mechanisms of RNA in one neurodegenerative disease	A potential new RNA drug candidate A startup to exploit the generated intellectual property
Teaching Science to Computers	Democratizing AI (safe, trustworthy, cheap, guaranteed performance)	Novel AI-based methods and knowledge for physicochemical processes	AI with computational efficiency and guaranteed performance via mathematical bounds
Technologies for Healthy Living	A home that takes care of us	Smart vectors for the precise delivery of therapeutics Investigate cause-effect relationships between biological and behavioral parameters and symptoms	Robot-based sensing solutions for personalized and preventive healthcare and independent living A closed-loop system with sensing and on-demand delivery of therapeutics

Flagship Program	Mid-term objective (year 3)	End-of-plan objective (year 6)
Technologies for Sustainability	Delivery of proof-of-concept demonstrators accompanied by life cycle assessments for sensors, actuators, and electronic systems with low energy requirements and based on sustainable materials for environmental monitoring and remediation	Delivery of one proof of value of the mid-term demonstrators for their market potential Delivery of proposals regarding low-emission technologies, substitution of critical materials, and end-of-life solutions for critical technology or products
Brain and Machines	Multiscale, multimodal description of brain activity and behavior needed to build computational models Testing interactive robots with partial autonomy with target users	Models of neural activity and behavior in perception, action, and interaction with others Autonomous adaptive robots for intuitive human-robot interaction
RNA Technology	Create novel drugs/artificial RNAs for disease treatment. Initiate start-ups and collaborations in the RNA domain. Lead a national RNA-focused scientific network under IIT's coordination	Progress an RNA molecule to the investigational new drug stage Develop proprietary RNA-based technologies Position IIT as a global powerhouse in RNA research
Teaching Science to Computers	Reveal, understand, and compute new fundamental principles of chemical and biological processes and of human behavior	Efficient and predictive algorithms and software to model complex chemical systems in biology, medicine, materials science, and for analyzing human behavior
Technologies for Healthy Living	Proof of concept of the intelligent and reactive environment (first validation of the network design criteria and technologies involved)	Quantitatively assess the value added to healthcare systems by intelligent and reactive environments

Cultural Heritage and Space Technology

One of the aspirations of IIT is to **continuously develop new applications** from the scientific and technological output of the Research Domains and Flagship Programs.

Two such applications stand out for their special relevance in Europe, one looking to the past and the other aimed at the future:

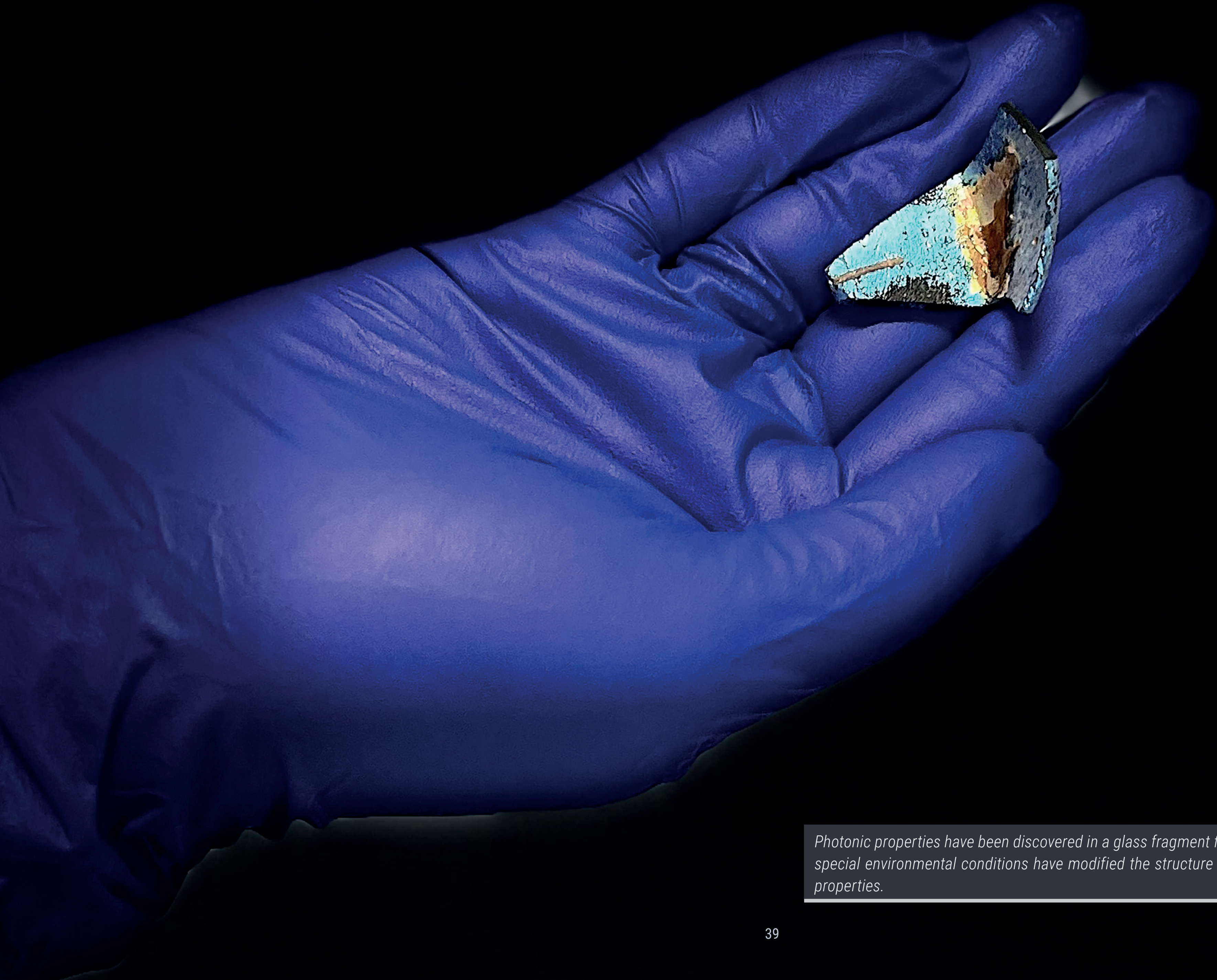
- Cultural Heritage;
- The Space Economy.

In the domain of **Cultural Heritage** IIT has launched a focused initiative, the Center for Cultural Heritage Technology (CCHT), located in Venice. CCHT harnesses IIT's expertise to further the understanding, preservation, and enrichment of Cultural Heritage in Italy and globally.

Examples of applications include: modern material characterization methods to precisely identify the structure of archeological samples; the use of robots for the 3D-4D digitalization of ancient manufacts; and the use of AI and satellite data to discover and protect heritage sites as part of a European Space Agency (ESA) project.

The **Space Economy** is booming, with an estimated value of around EUR 0.5 T in 2022. IIT has earned a solid reputation as a technological provider. In the field of new biomaterials, IIT's PIs have secured grants from the ERC and the Italian Space Agency (ASI).

ASI and its European counterpart (ESA) have funded space-related projects at IIT worth about EUR 20 M, including a Gamma/X-ray graphene-based nanodetector. IIT has become a selected provider for Thales-Alenia Space. A planned Joint Laboratory with ASI is expected to launch in 2024.



Photonic properties have been discovered in a glass fragment from the ancient Aquileia. Time and the special environmental conditions have modified the structure of the glass, giving it special photonic properties.

Technology Transfer

Technology transfer has two major targets: industry and healthcare.

The technology transfer mission encompasses several actions that aim to consolidate connections with industry and healthcare institutions (the external stakeholders) while educating scientists of all ranks to develop an entrepreneurial mindset (the internal stakeholders).

Action plan for the external stakeholders:

- Create an Industrial Liaison Program (ILP) to address the high technology readiness level (TRL) needs of industry;
- Launch Systemic Joint Laboratories for the low TRL research needs of small and medium-sized enterprises (SMEs).

Action plan for the internal stakeholders:

- Improve our training programs to guarantee PIs can lead technology development to market;
- Strengthen the instruments in support of entrepreneurship.

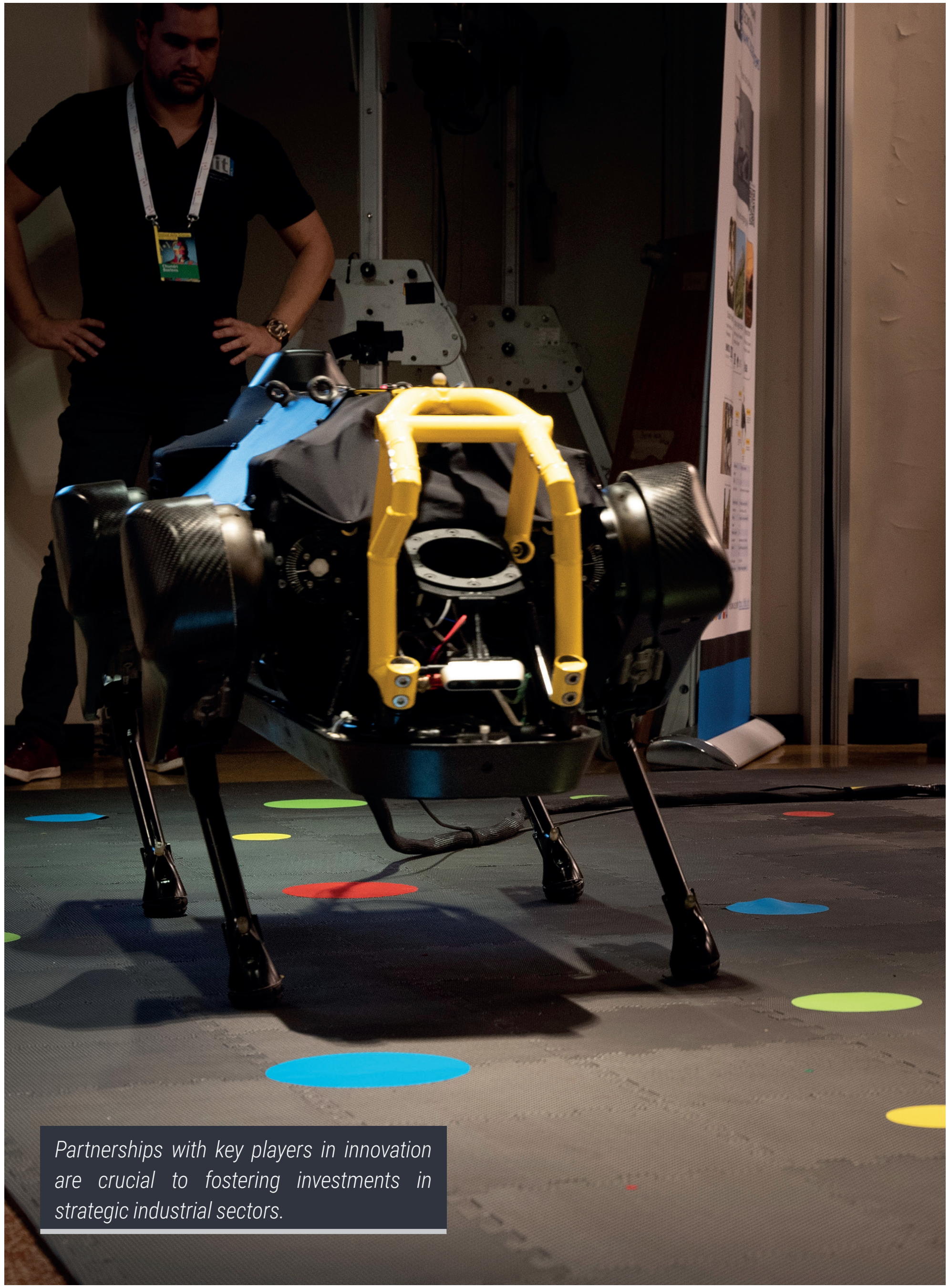
IIT's Industrial Liaison Program (ILP) will connect companies to our Research Units and Facilities in order to create networks that can address the complex projects of technological innovation. Inspired by MIT's industrial liaison program, the ILP includes a 'fidelization' program with a tier system and relative tier membership fees. The ILP offers a set of services depending on the tier level. In general, the higher the tier, the wider the access to IIT's resources. Resources can be a specific piece of technology, technical knowledge, development support, or training. Our existing Industrial Facility will work as the main entry point to the program.

The Systemic Joint Laboratory (SJL) is a Joint Lab established with an association, a territorial district, or any other form of aggregate set of companies. By following the model of the Intellimech-IIT Joint Lab at Kilometro Rosso (Bergamo), an SJL agreement with IIT will enable groups of SMEs to jointly invest in long-term innovation activities of common interest. SJLs will facilitate large research and development investments in cases where it is unlikely that any single company would have the means to invest in isolation. SJLs will foster investments in strategic industrial sectors (and territorial districts) such as aerospace, automotives, medical tech, and agritech.

We identify the technology transfer priorities by analyzing our TRL against a reduced set of EU NACE industrial sectors.

The ILP and SJLs will prioritize companies in high-readiness sectors in Europe and beyond. We will invest our resources in the areas that are most likely to increase our technology transfer output.

Sector vs. RD	Robotics	Nanomaterials	LifeTech	Computation
1. Agritech	HIGH	HIGH	MEDIUM	MEDIUM
2. Mining	MEDIUM	MEDIUM	LOW	MEDIUM
3. Manufacturing	HIGH	MEDIUM	LOW	HIGH
4. Energy	LOW	HIGH	LOW	HIGH
5. Water	MEDIUM	HIGH	LOW	MEDIUM
6. Construction	MEDIUM	MEDIUM	LOW	MEDIUM
8. Transport	HIGH	LOW	LOW	MEDIUM
10. ICT	LOW	LOW	LOW	HIGH
13. R&D	HIGH	HIGH	HIGH	HIGH
15. PA & Defense	HIGH	HIGH	MEDIUM	HIGH
16. Education	MEDIUM	LOW	LOW	MEDIUM
17. Health	HIGH	MEDIUM	HIGH	HIGH



Partnerships with key players in innovation are crucial to fostering investments in strategic industrial sectors.

With respect to healthcare, SJLs will leverage the existing hospital and IRCCS network to create large thematic networks of companies and hospitals. The goal will be to transfer IIT's research to the clinic. Direct collaboration with healthcare stakeholders will facilitate the patient-centered approach that is essential for technological innovation in the field. Recent examples of this approach include the INAIL-IIT hand prosthesis project (Hannes), the use of robots (iCub) for cognitive rehabilitation, and the use of clinical genomics for precision medicine in Liguria and Valle d'Aosta.

To address the internal stakeholders, i.e. our researchers, we will provide further support on the path to entrepreneurship by streamlining training activities and launching new initiatives of business incubation and acceleration.

This includes the collaboration with Bocconi for Innovation (B4I), the SPARK Stanford Biotech Accelerator, the UC Berkeley Skydeck acceleration program, and several other partners. The goal is to build a branded IIT School that encompasses scientific subjects as well as economic, managerial, and entrepreneurial training courses (see "People and Higher Education" on page 42).

Three additional elements support the creation of new businesses:

- The IIT incubator (H^4E);
- The RoboIT agreement with CDP Venture;
- The RAISE NextGenEU project.

The incubator will host new businesses on site, linking them directly with IIT's laboratories. RoboIT invests in proof-of-concept projects and also provides seed funding for selected projects. RAISE will implement an acceleration program (IIT^4) that systematizes: 1) technological acceleration (i.e. access to IIT know-how and facilities); 2) business acceleration to design the business models connected to the use of new technologies; and 3) financial acceleration, which provides access to IIT's network of venture capitalists and business angels.

People and Higher Education

IIT recognizes the importance of attracting and retaining talent. We carefully monitor the size and composition of our talent pool. We plan our actions by considering retirement, dropouts, and elements that influence the talent pool composition (e.g. the job market, remuneration levels, attractiveness factors).

Our Action Plan develops along three major axes:

- Drive recruitment in line with detailed analyses of gaps (including gender and, in general, diversity aspects) at the level of individual teams, Research Domains, Flagship Programs, and taking into account ensuing technological trends;
- Implement a solid higher education program to address scientific and professional development at all career levels, from onboarding to alumni;
- Create a career-long mentoring program including career advice, perspectives, and supervised placement schemes.

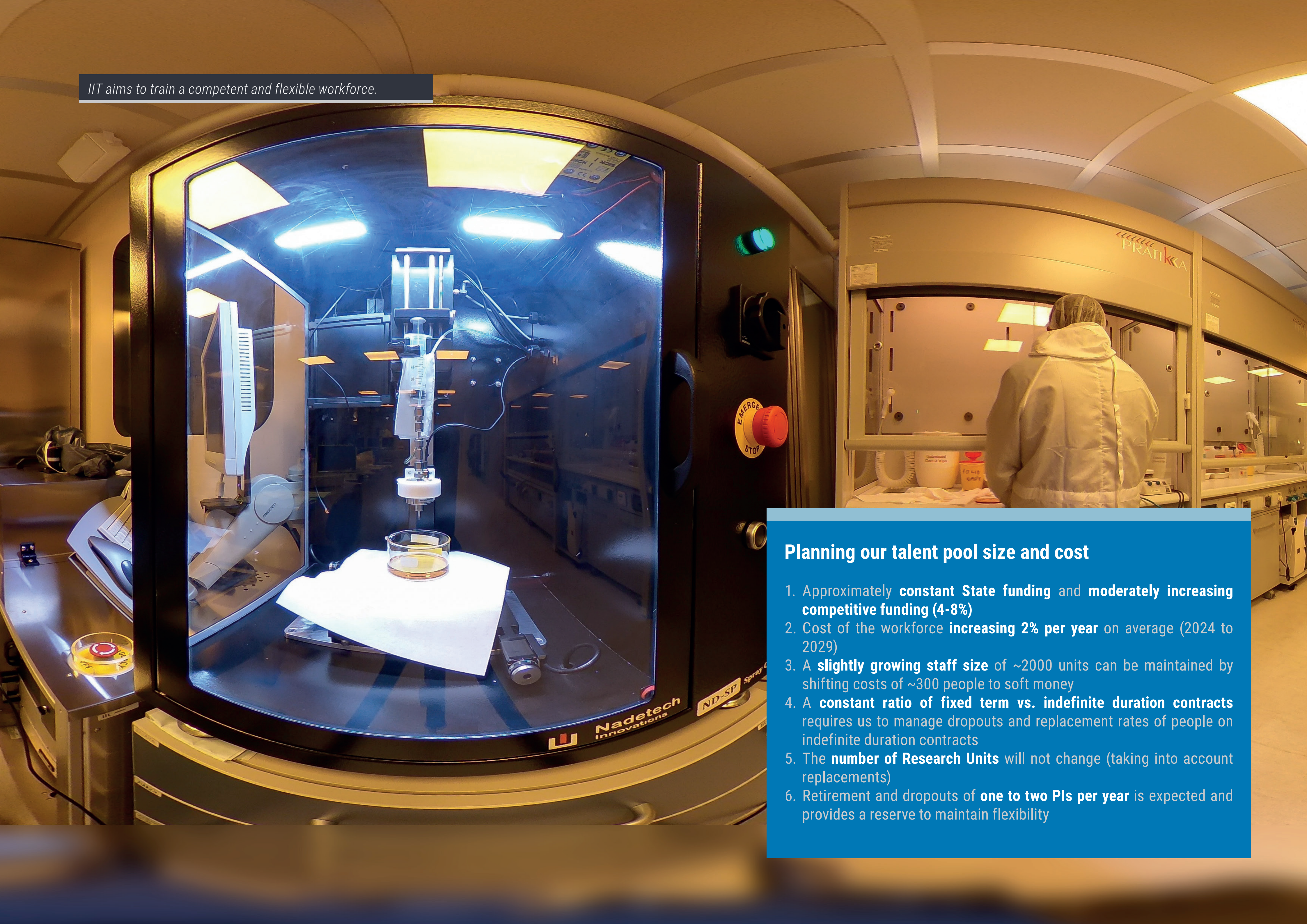
IIT aims to train a competent and flexible workforce that is suitable for both academia and industry and internationally competitive in various domains (science, communication, innovation). The Higher Education Office (HEO) is the principal instrument for designing education at IIT. We follow the principles of the Hannover Conference[18], laying the groundwork for the continuous professional development (CPD) that characterizes scientific career paths.

We will launch a program of internationalization called IIT Global. For a selected number of partners, we will: 1) activate students and faculty exchange (sabbaticals, long stays, visiting researcher scheme); 2) create dual-site Joint Labs, thus initiating a longer-term collaboration; and 3) establish an IIT Outstation at selected locations. In 2023, we started on the path to this internationalization program with A*STAR in Singapore, UC Berkeley, Stanford Medicine, the European Molecular Biology Laboratory (EMBL), and the University of Osaka. We will also inject fresh resources into the MIT and Harvard Outstations.

IIT Global will include a technology transfer twist. For example, we have signed a preliminary agreement with the UC Berkeley SkyDeck acceleration program. Additionally, we will target scientific and technological cooperation in bilateral and multilateral programs such as the UN, IFI, EU, NATO, and EDA.

18 https://www.doctoral-education.info/hannover-recommendations.php.

IIT aims to train a competent and flexible workforce.



Planning our talent pool size and cost

1. Approximately **constant State funding** and **moderately increasing competitive funding (4-8%)**
2. Cost of the workforce **increasing 2% per year** on average (2024 to 2029)
3. A **slightly growing staff size** of ~2000 units can be maintained by shifting costs of ~300 people to soft money
4. A **constant ratio of fixed term vs. indefinite duration contracts** requires us to manage dropouts and replacement rates of people on indefinite duration contracts
5. The **number of Research Units** will not change (taking into account replacements)
6. Retirement and dropouts of **one to two PIs per year** is expected and provides a reserve to maintain flexibility

The budget of the Strategic Plan vs. the past

The following graphs and tabular data show the foreseen allocation of resources in comparison to the 2018-2023 period. We highlight the general envelope (Figure 5), the distribution across Research Domains (RDs) (Figure 6), the evolution in human capital (FTE and cost in Figure 7), the research investment vs. other costs (see table A), the type of expenditure (see table B), and the estimated allocation to the Flagship Programs vs. Blue Sky Research (see table C).

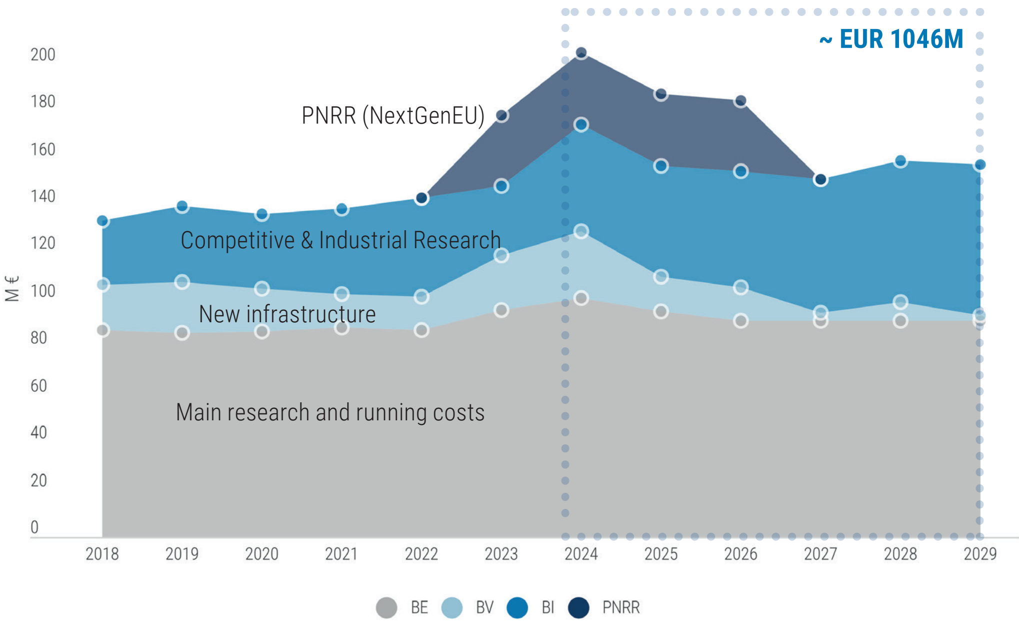


Figure 5: The general envelope of the budget: 2018-2022 from balanced books; 2023-2029 estimated from current budget and projections. Color coding shows the main State Budget (■), the Capital funds invested (■ : Brain Magnet Program, CHT and CCHT investment and the infrastructure/energy saving plans), the Competitive funding (■ : 2018-2023 with a CAGR of 14%, 2024-2029 with a CAGR varying from 4% to 8%) and, finally, the NextGenEU program (■). Figures in EUR M.

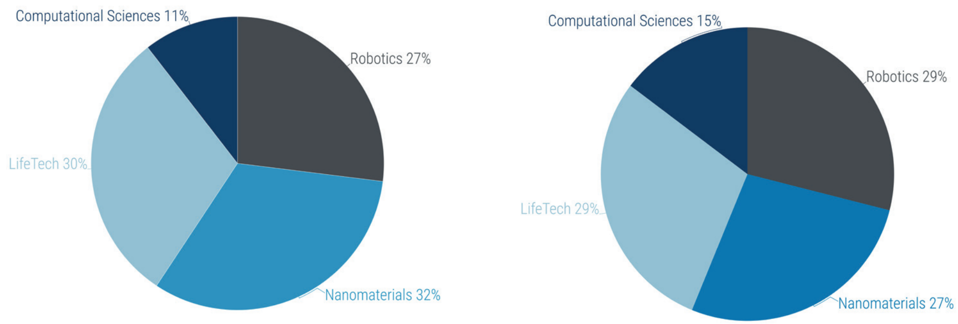


Figure 6: Percentage-wise investment in the RDs with a commitment to increasing investment in Computational Sciences and Robotics relative to the 2018-2023 period.

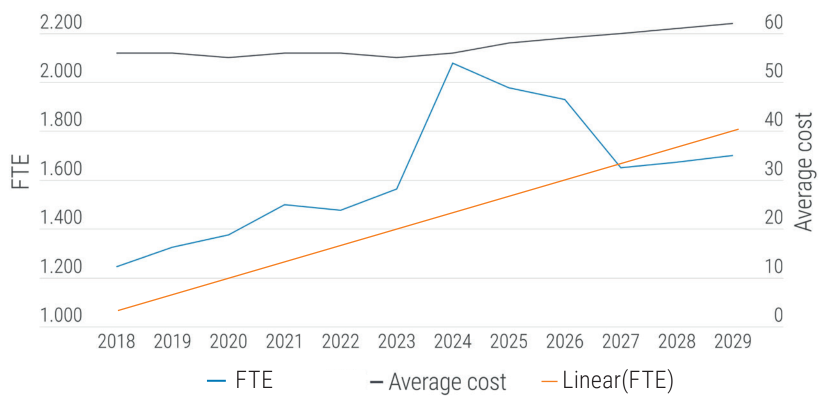


Figure 7: The evolution in human capital (staff size), taking into account exogenous factors (in the form of 2% yearly increase of the cost of labor) vs. the available funds. FTE without PhD students are shown in orange, the cost pro capita in blue (in EUR K). The trend remains positive because of the increase in competitive funding. Retirement is a negligible factor in the dynamics of the evolution in staff size.

	2018-23	2024-29
Robotics	168.337	211.604
Nanomaterials	201.928	198.792
LifeTech	188.416	212.694
Computational Sciences	65.567	107.425
Total Research	**624.247**	**730.515**
Infrastructure	137.243	167.166
Support	48.330	61.961
Administration	48.507	74.306
Governance	12.897	11.215
Total other	**246.977**	**314.647**
Grand Total	**871.224**	**1.045.162**

(A) Comparison of the 2018-2023 and 2024-2029 budgets. Table shows the size of the direct allocation to research, the cost of infrastructure, support (including technology transfer, research organization, and dissemination), administration, and governance. The total budget grows while controlling the relative allocation to the various components. All figures in EUR K.

	2018-23	2024-29
OpEx	287.525	313.973
CapEx	112.140	79.598
Personnel	471.560	651.591
Total	**871.224**	**1.045.162**

	2018-23	2024-29
OpEx	33%	30%
CapEx	13%	8%
Personnel	54%	62%
Total	**100%**	**100%**

(B) Comparison of the 2018-2023 and 2024-2029 budgets by type of expenditure. Note the reduction in the investment in CapEx because the major acquisition of IIT's premises was completed in 2023. All figures in EUR K.

	2024	2025	2026	2027	2028	2029
Blue Sky Research	50.304	45.495	45.399	34.818	37.657	36.954
Technologies for Sustainability	26.408	23.883	23.833	18.278	19.769	19.400
Brain & Machines	26.940	24.364	24.313	18.647	20.167	19.790
RNA Technologies	17.446	15.778	15.745	12.075	13.060	12.816
Teaching Science to Computers	11.019	9.966	9.945	7.627	8.249	8.095
Technologies for Healthy Living	14.506	13.120	13.092	10.041	10.859	10.657
Total	**146.623**	**132.607**	**132.327**	**101.486**	**109.760**	**107.712**

(C) Estimated size of the investment in Blue Sky Research vs. the Flagship Programs in the period 2024 to 2029. Note that about 1/3 of the total allocation of research is devoted to Blue Sky Research. All figures in EUR K.

Focus on the NextGenEU/PNRR

IIT participates primarily in the Mission 4 of the National Program of Recovery and Resilience (PNRR) (mostly associated with the Ministry of Research's calls). More specifically, we are partners in:

- Three Innovation Ecosystem & Infrastructure projects;
- Three Extended Partnerships;
- Three National Centers;
- One project as part of the PNRR's Complementary Fund.

IIT is also partner in four projects of the Mission 6 (associated with the Ministry of Health).

The total value of IIT's NextGenEU/PNRR projects is around EUR 115 M. Direct funding for research and development (including overheads) is EUR 77.3 M, cascade funding is EUR 26.7 M, allocation to open calls is EUR 6 M, and about EUR 1.3 M goes to support PhD students.

Notable activities are related to technology transfer via the RAISE Innovation Ecosystem project based in Genoa (mainly robotics and AI), the CoSyET Innovation Infrastructure based in Turin (technologies for energy transition), the National Centers on HPC and RNA Technologies, and the FAIR partnership on AI. The Fit4Med project funded by the PNRR's Complementary Fund focuses on robotics for healthcare. The themes of the NextGenEU/PNRR projects all directly connect with the topics of this Strategic Plan as follows:

- Technologies for Sustainability relates to CoSyET and the National Biodiversity Future Center;
- Brain and Machines is supported by FAIR and Fit4Med;
- Teaching Science to Computers has contributions from the National Center on HPC, Big Data and Quantum Computing, and the FAIR partnership on AI;
- RNA Technologies is fully integrated with the National Center on Gene Therapy and Drugs based on RNA;
- Technologies for Healthy Living is completely aligned with Fit4Med.

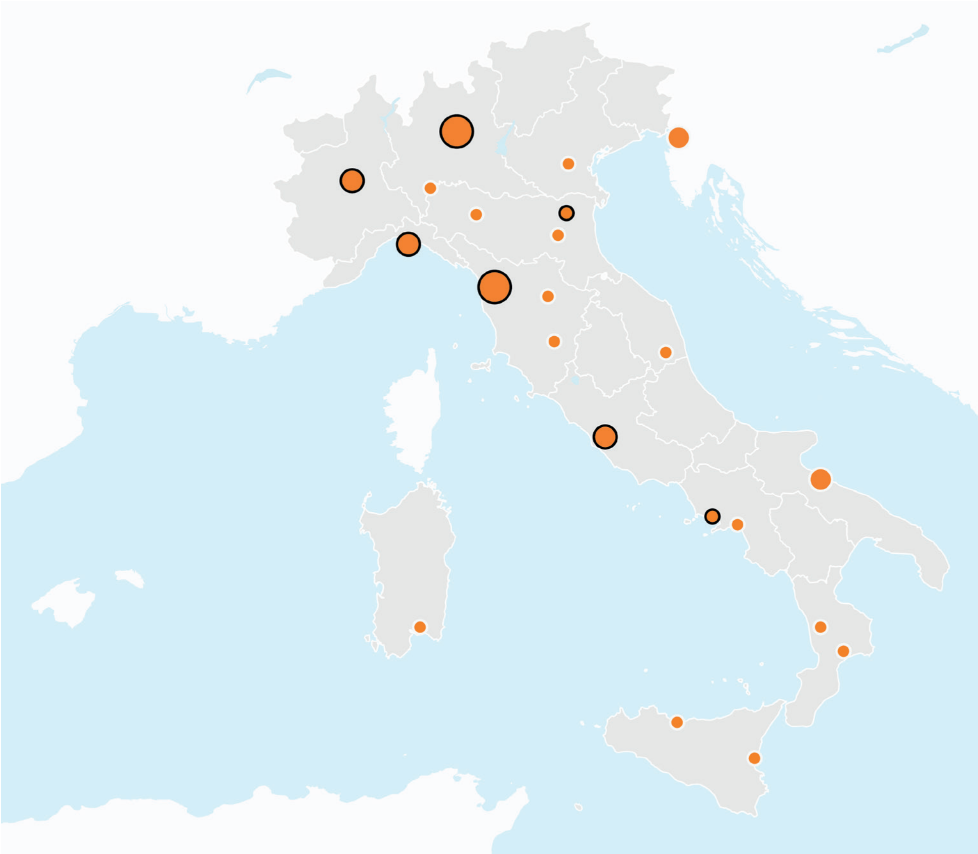
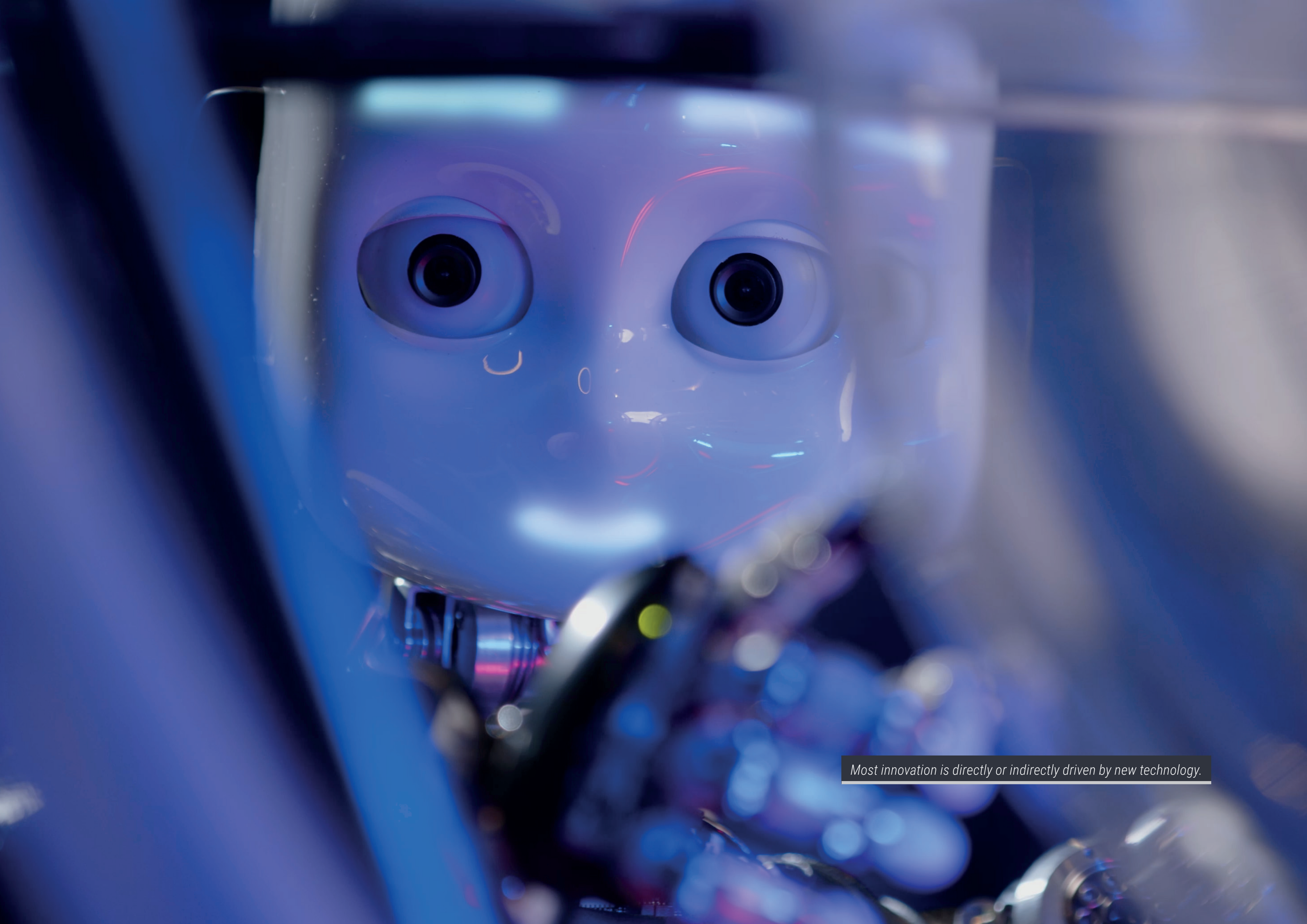


Figure 8: Partners in NextGenEU/PNRR projects. The size of the placeholders is proportional to the number of agreements. Placeholders with a black border also correspond to the presence of a center of the IIT network.



Most innovation is directly or indirectly driven by new technology.

The Strategic Plan in a nutshell

What	Actions	Investment
Digitalization & AI (AI first!)	1) Increase research investment 2) Recruit and educate 3) Design procedures for data curation 4) Digitalize laboratory infrastructure 5) Improve computational infrastructure	~EUR 150 M
Data Management (as part of AI first!)	1) Infrastructure by providing seamlessly integrated services and tools 2) Policies to set objectives and provide guidance on the production of FAIR-by-design data 3) Human resources by integrating a (new) skilled workforce of IT and data professionals to support scientists	Part of Digitalization & AI
Blue Sky Research	1) Scientific management: evaluation processes that value discovery and assess excellence only 2) Attract the best minds on the market 3) Maintain and upgrade the laboratory infrastructure	EUR 251 M
Flagship Programs	Intercept: 1) Societal megatrends: global warming and the aging population 2) Emerging technological needs: energy transition, technologies bioengineering and healthcare, the digital transition 3) Technological trends: artificial intelligence and its subdisciplines 4) IIT's specific strengths emerging from either Blue Sky Research or the Research Domains	EUR 480 M
Further aspirations	1) Cultural Heritage (Venice/CCHT) 2) Space Economy (Genoa/CJIR)	~EUR 5-6 M
Better infrastructure	1) Renovation of the infrastructure and physical plant (quality of internal and laboratory space, new laboratories, common/shared space) 2) Maintain and upgrade equipment (invest in the most critical labs and increase dependability of equipment) 3) Save energy (target 55% renewable by 2030)	EUR 37.5 M
Network Centers	Guaranteeing sustainability and quality: 1) Search for better location/infrastructure 2) Maintain thematic structure and unitary vision	Part of the infrastructure
Sustainable energy	Increase/improve: 1) Use of efficient technologies 2) Renewable sources 3) Different purchasing strategies and services 4) Waste management/waste reduction processes	~EUR 13 M
Higher Education	Address: 1) Scientific and professional development at all career levels 2) Career-long mentoring programs3) IIT Global internationalization program	~EUR 1.5 M
Technology Transfer	External stakeholders: 1) Create the Industrial Liaison Program 2) Launch the Systemic Joint Laboratories program Internal stakeholders: 1) Improve training programs for researchers 2) Strengthen the instruments in support of entrepreneurship	~EUR 3 M

The expected impact of the Strategic Plan's output

What	Expected impact	Type
Digitalization & AI Data Management	Transform how computation drives science and technological development, how data are stored and used by AI	Internal
Blue Sky Research	Internal: design the future directions of IIT's scientific discovery External: contribute to the development of scientific knowledge and its translation into technology	Internal/External
Flagship Programs	Technologies for Sustainability will contribute to the establishment of circular economy paradigms (e.g. electronics) and to the design of new materials for the energy transition (e.g. reduce dependency on critical materials and improve efficiency) Brain and Machines will impact our understanding of computation in the brain and machine learning methods for embodied systems (i.e. interactive robots). It will also translate this new knowledge into interventions for neurological and neuropsychiatric disorders (e.g. autism) RNA Technology will adopt a strong translational focus so that the study of RNA will generate new methods of drug engineering. The main target is precision medicine for neurodegenerative diseases and cancer Teaching Science to Computers will improve our understanding of the mathematics of machine learning & AI. It will impact the development of bespoke methods for chemistry and physics. It will contribute to the design of trustworthy AI with applications in robotics and automation Technologies for Healthy Living will develop tools to measure the status of patients in daily living contributing to a paradigm change in the delivery of medical services. It will integrate big data in order to design and focus therapeutic interventions (precision medicine)	External
Further aspirations	Deploy materials engineering and digital technologies to two strategic sectors of the Italian economy: cultural heritage and space	External
Better infrastructure	Impact the attractiveness of IIT and its sustainability (e.g. ESG targets)	Internal
Network Centers	Impact IIT's collaboration with the national academic system as well as its attractiveness and sustainability	Internal/External
Sustainable energy	Positively impact IIT's financial sustainability but also align our research objectives (e.g. sustainability) with ESG objectives	Internal
Higher Education	Increase IIT's attractiveness via a strong education program. Impact the national industrial system by training young professionals in STEM	External
Technology Transfer	Internal: increase attractiveness and career opportunities External: impact the national industrial system by directly providing technical solutions (see the expected impact of the Flagship Programs)	Internal/External

Improving efficiency in the use of alternative energy and feedstocks are key objectives to deliver sustainability-compliant technologies.

Appendix 1: The Flagships Programs

The **five Flagship Programs** introduced on page 20 aim to confront large-scale problems, which require extremely transversal skills and large collaborative teams.

Flagship Programs are visionary large-scale collaborations (larger than one-to-one collaborations) across Research Units and Domains with **well-defined ambitious goals**. Flagship Programs aim to consolidate IIT's presence and visibility in the respective research sector.

Each Flagship Program devises methods and experiments, engineering practices, and competitive funding strategies to achieve its objectives, potentially adapting on the fly as curiosity leads to new research directions. To guarantee that new ideas are always nurtured and potentially incorporated into the progression of the Flagship Programs, PIs will follow new leads in search of the unexpected by participating in the Blue Sky Program (see "Blue Sky Research@IIT" on page 32).

The business case for the Flagship Programs relies on the proven track record of technology transfer towards industry and the clinic. With respect to the latter, we mainly liaise with the Italian research hospitals (IRCCS). The objectives of the Flagship Programs thus include both scientific and technology transfer goals.

We describe the five Flagship Programs below.

Technologies for Sustainability

The Technologies for Sustainability Program covers several areas of the general challenge of sustainable development (the Earthcare societal challenge set out on page 12). It mostly develops a plan of research, starting with technology derived from our solid tradition of materials sciences, combined with the next generation of electronics, robotics, and AI. Areas of application are energy, recycling and upcycling, water treatment and remediation, agricultural systems, ocean monitoring, and green electronics and robotics. All areas are clearly connected to the UN's Sustainable Development Goals but also with the investment areas of the EU and especially the NextGenEU program (the Ligurian Innovation Ecosystem project RAISE, the Innovation Infrastructure to be installed in CSFT/Turin, CoSyET, and the participation in the National Biodiversity Future Center).

IIT has pioneered the concepts of recovering renewable and nonrenewable biomass and other wastes (e.g. CO_2, end-of-life materials from electronic appliances) to develop sustainable, high value-added materials for reintroduction to the market.

Improving efficiency in the use of alternative energy and feedstocks are key objectives to deliver sustainability-compliant technologies.

IIT's total investment (see The budget of the Strategic Plan vs. the past on page 28) is about EUR 8 M/year with the contribution of 34 Research Units and Facilities and more than 60 researchers. In addition, the Program manages about EUR 24 M/year of EU projects and NextGenEU/PNRR. About EUR 2 M are earmarked to support PI-to-PI collaborations during the period of the Strategic Plan (2024-2029).

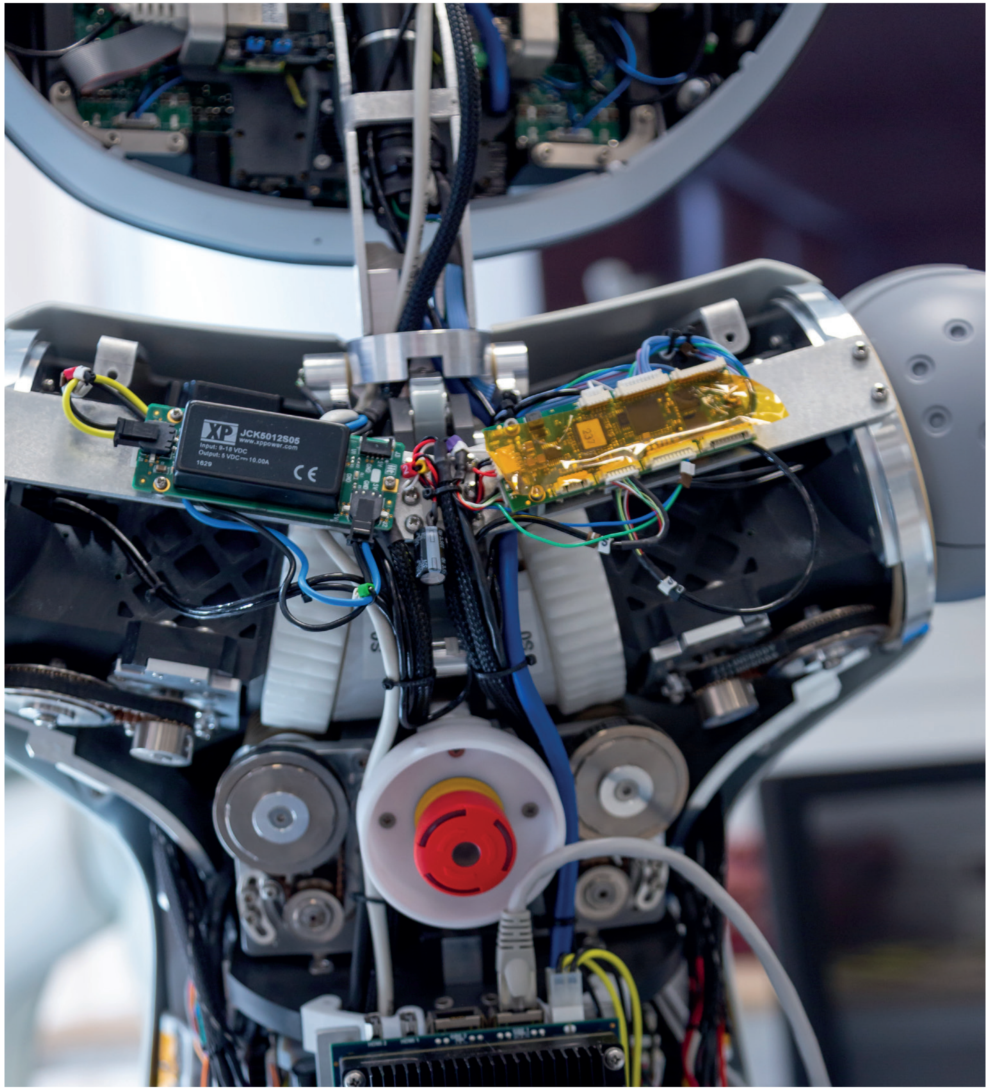
With respect to sustainable energy, the Program will investigate (photo)catalysis, hydrogen, green fuels, photovoltaics, and energy storage at various technology readiness levels (TRL from 1 to 5). We will develop new materials, devices, and entire systems, with emphasis on characterization in operando.

Examples include: 1) green fuels (CO_2 capture and valorization, electro-/photocatalysis, electrolyzers, fuel cells); 2) solar energy conversion and storage (perovskites for photovoltaics and nonphotovoltaic materials); 3) energy storage (batteries, high-performance secondary batteries, printable and organic electronics); and 4) energy transport-distribution-transfer-management (wireless energy transfer).

In the applications of recycling and upcycling, this Program will focus on the recovery of raw materials, organic and inorganic, from different resources , mainly wastes and biomass, to develop new advanced materials with minimal carbon footprint. As part of the recycling effort, we note the increasing trend of depolymerization via AI-optimized enzymes as well as the prediction of the physical and mechanical properties of materials.

On the topic of water remediation and aquatic life, the Program will deal with the development of new functional materials and advanced processes to efficiently recover freshwater from unconventional sources such as wastewater, seawater, and atmospheric humidity. Fully sustainable materials and processes will be elaborated (e.g. minimization of energy usage and further waste byproducts).

For monitoring the quality of water, we will design label-free sensors, lab-on-chip miniaturized devices, pollution indicators, and reporter-based cell lines in order to enable on-site checks of water quality and water purification systems. Our experimental studies will be supported by simulations and modeling of the interactions of enzymes and microorganisms with emerging pollutants (i.e. PFAS, nano/microplastics) and their biodegradation. Monitoring, measuring, and protecting the oceans will help us understand how life interacts with a variety of pollutants, and thus allow us to assess health problems due to waste and pollution in general.



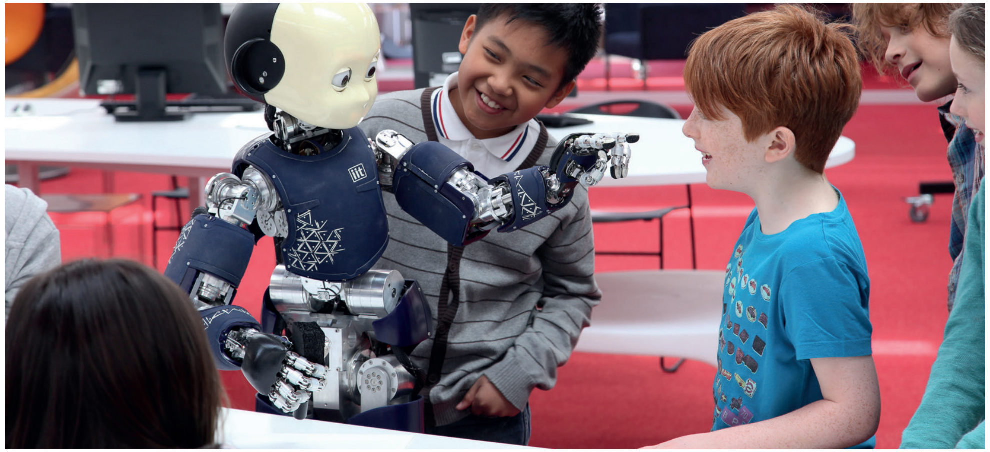
Advances in materials science and the adoption of bioinspired design principles offer new ways to construct and operate robots.sustainability-compliant technologies.

Robotics will impact applications such as environmental monitoring, precision agriculture, reforestation, biodiversity protection and remediation. Unfortunately, as for many technologies, electronic garbage may become a top contributor to waste generation, creating a negative net impact. The Technologies for Sustainability Program aims to create robotic platforms made of biobased, biodegradable, resilient (soft)robots that are healable, deformable, self-growing, self-adapting, and resistant in complex environments. AI-based approaches and on-board neuromorphic low-power logic will control these robots. Scientifically, the design of green electronics and robots is an enormous opportunity for a paradigm shift that should be pursued vigorously.

In terms of technology transfer, we will further our activities in the biomaterials sector, which spun off one startup in 2022. Promising new directions are related to the Joint Lab with the Italian Mint Institute (Istituto Poligrafico della Zecca dello Stato). Research in this direction aims to eliminate any nonrecyclable/nonbiodegradable materials from the production cycle.
To avoid duplication, Technologies for Sustainability will liaise with and use the tools for AI and simulations developed by the Teaching Science to Computers Program. Further, the Technologies for Sustainability Program will participate in the development of the Automated Synthesis Lab and adopt standards and methods of data collection and storage. This Program will also use all of IIT as a testing ground or large living laboratory, in which solutions will be tested in order to optimize their functions and increase their TRL in preparation for technology transfer.

Brain and Machines

The Brain and Machines Program is a comprehensive endeavor that gathers PIs with expertise in cellular, circuit, systems, and cognitive neuroscience, while reaching out to robotics and embodied AI. The Program aims to understand, in selected cases, brain function and dysfunction, to model behavior, and to design autonomous robots based on the knowledge obtained from neuroscience research. The Program compares favorably with similar international research departments, such as the MIT Brain and Cognitive Sciences (BCS). With 32 PIs, the MIT BCS cover four areas of expertise that match our Program well. Similar neuroscience programs exist in other excellent institutions (e.g. Graduate School of Systemic Neuroscience at Ludwig-Maximillians-Universität, Institute of Cognitive Neuroscience at University College London). This shows the renaissance in interest in these themes within the computational and cognitive science communities.



Computational models of the functional brain architecture underlying animal behavior can be effectively tested in human-robot interactions.

The Brain and Machines Program at IIT has several noteworthy aspects including a unique history of developing embodied AI in sophisticated robot systems, and the ability to measure the brain at multiple scales with a wide spectrum of techniques.

IIT's total investment (see The budget of the Strategic Plan vs. the past on page 28) is about EUR 9 M/year with the contribution of 50 Research Units and Facilities and a team of about 75 researchers (students, postdocs). In addition, the Program manages about EUR 14 M/year of EU projects and NextGenEU/PNRR. About EUR 2 M are earmarked to support PI-to-PI collaborations during the period of the Strategic Plan (2024-2029).

The Brain and Machines Program will develop along four major research directions:

- Computational: Identifying computational mechanisms of brain function;
- Cognitive: Understanding the brain in perception, cognition, action, and interaction;
- Embodied Artificial Intelligence: Building intrinsically embodied artificial intelligence (interaction of body and control);
- Clinical: addressing cognition and interaction in neurotypical and neurodiverse individuals.

On the computational side, the Brain and Machines Program will investigate the fundamental rules governing brain computations across scales, from the synaptic and cellular level to the circuit, systems, and behavioral level.

This will be performed by combining state-of-the-art technologies (electrophysiology, optogenetics) with advanced analytical approaches in animal models and humans:

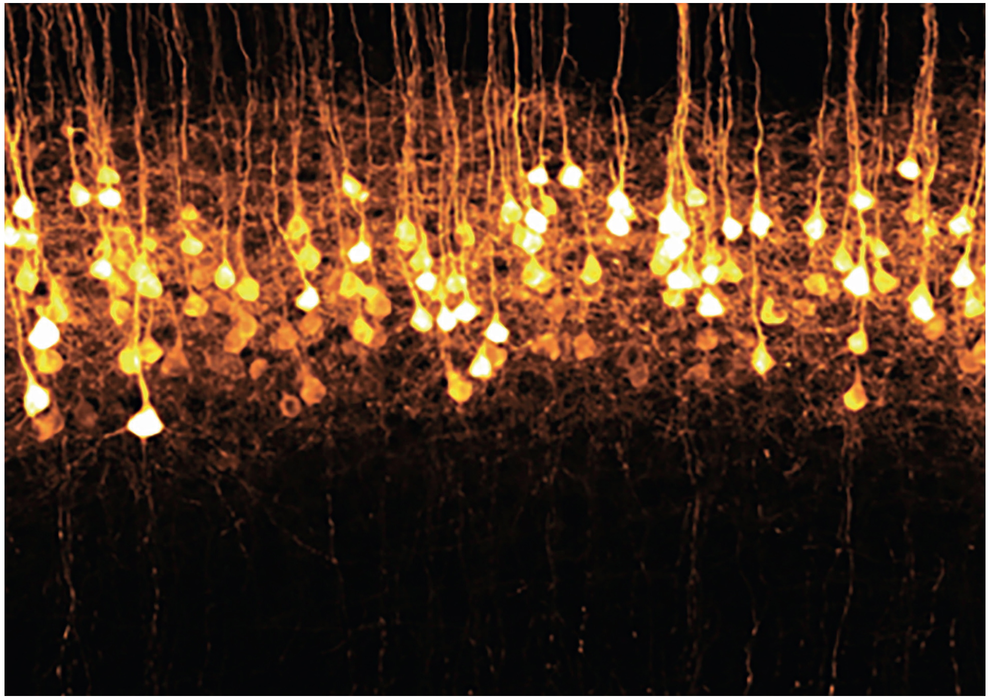
- At the synaptic and cellular scale, we will study how dendrites perform computations. Specifically, we will investigate how the relative distribution of excitatory and inhibitory synapses results in nonlinear input summation;

- At the circuit scale, we will identify the computations supporting cognitive and behavioral flexibility, and we will investigate the contribution of neuromodulatory signals in shaping circuit computations and information transfer across functionally distinct brain areas;

- Finally, at the behavioral level, we will determine how the neural dynamics in specific brain circuits map onto behavioral states in animal models.

Computations occurring at finer spatial scales (e.g. synaptic and cellular level) will be described and interpreted with respect to their potential contribution to the computations occurring at larger scales (e.g. circuit, systems, and behavioral levels).

On the cognitive side, the Brain and Machines Program will aim to provide mechanistic explanations for brain functions by studying sensory processes such as attention, action planning, and motor control, as well as body perception and peri-personal space.



Optogenetic manipulation is an effective tool for investigating cortical microcircuits.

Methodologically speaking, our cognitive neuroscience agenda will take the following approaches:

- Using behavioral and neural measures (motion capture, eye tracking, thermal imaging, electrophysiology, EMG, fMRI, TMS), we will develop experimental protocols in which humans or animals perform perceptual or cognitive tasks;

- We will move beyond classical cognitive neuroscience protocols towards more ecologically valid and interactive experimental designs, where we will study interaction with the environment and with other agents – in dyads and groups, involving natural (human and animal) and artificial (virtual and physical) agents. We will analyze inter-brain and inter-body synchronization and also use brain stimulation techniques to unravel mechanisms of social communication.

For Embodied Artificial Intelligence, the Program will:

- Develop computationally efficient and data-efficient learning algorithms, multimodal models for embodied systems (robots), active sensing and self-supervised learning, bioinspired computation;

- Advance the design of robot controllers that can sense, perceive, reason about, and react to the environment, including the social environment, based on insights from cognitive neuroscience;

- Develop adaptive behavior for long-term autonomy, such as motion planning, control of manipulation and locomotion, social and physical human-robot interaction, neuroscience models of cognitive mechanisms (on robots), shared autonomy, and multimodal sensory feedback;

- Design body intelligence: i.e. structure, actuation, and sensing following biologically accurate principles for robot/machine optimization, morphological design based on compliant bodies with affordable actuation and sensing, mechatronics and robot design using rigid and soft materials for fault-tolerant behavior and adaptation (the new iCub).

The Program's clinical aspect will focus on brain dysfunction, including:

- Isolating and changing the neural mechanisms underlying typical and atypical neurodevelopment across the lifespan and in neuropsychiatry;

- Developing targeted rehabilitation protocols and/or more precise diagnosis with personalized approaches that maximize therapeutical outcomes;

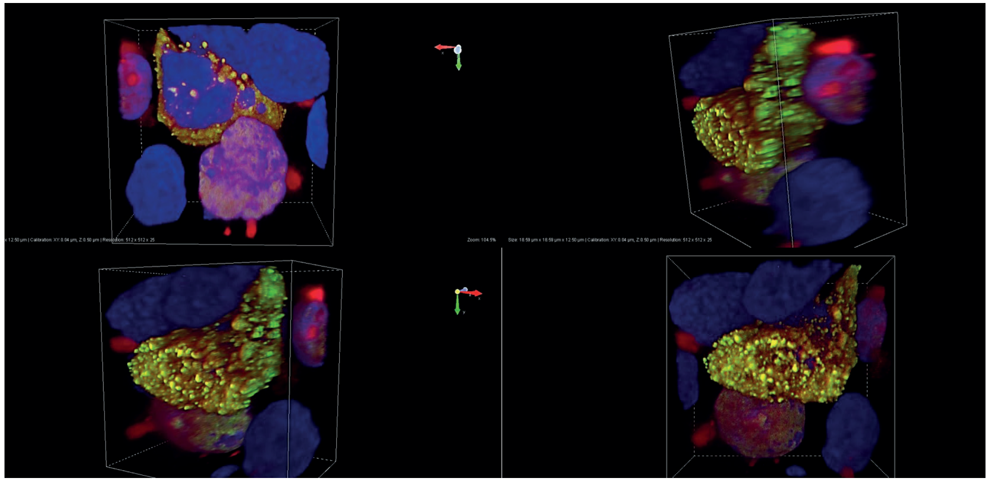
- Designing novel intervention methods, such as robot-assisted training (RAT) or drugs to treat socio-cognitive impairments.

The Program's research will also be instrumental for technology transfer and start-up creation, particularly in the areas of wearable technologies, collaborative and rehabilitative robotics, robots for the exploration of unstructured environments, AI, and precision instruments.

RNA Technologies

The RNA Technologies Program aims to create groundbreaking knowledge in RNA biology, RNA technologies, and drug discovery. The Program receives contributions from several PIs with expertise in fundamental molecular biology of (noncoding) RNA and RNA-protein interactions (AI-based simulations), RNA mechanisms in cancer, RNA delivery, RNA-based medicine manufacturing, and the profiling of clinically relevant RNAs.

The Program can also draw on special relationships with hospitals in Genoa (Gaslini Children's Hospital and the San Martino Hospital) and Aosta (the CMP³VdA project) with computational and medical genomics in collaboration with Parini Hospital. By accessing patient data from IIT's clinical partners, the RNA Technologies Program can address the needs of personalized medicine.



RNA probes can be used as detection tools to track the progress of protein aggregation in diseases.

There are relatively few RNA-centered clusters/institutes worldwide. Notable examples are UC Santa Cruz, University of Massachusetts, Australian National University, the Catalan CRG, and University of New South Wales. These are all quite recent endeavors. By establishing the Center for Human Technologies (CHT) in Genoa in 2017 and the subsequent RNA Initiative in 2020, IIT gained a headstart in developing various technical tools in hardware (e.g. sequencing, omics) and software (e.g. variant calling, molecular simulations, nanopore data analysis).

Our PIs have secured EUR 35 M in external funds to support the RNA Program. The nature of the RNA Program as a coherent scientific cluster, and its unitary scientific vision was instrumental to securing a large share of the budget of the NextGenEU/PNRR-sponsored National Center for Gene Therapy and Drugs based on RNA Technology. Fifteen PIs, many of them part of the RNA Technologies Program, have received a total of EUR 11 M in the framework of the National Center. Their activities map closely onto the program itself.

IIT's total investment (see The budget of the Strategic Plan vs. the past on page 28) is around EUR 5 M/year with the contribution of 21 Research Units and Facilities and more than 45 researchers. In addition, the Program manages about EUR 9 M/year of EU projects and NextGenEU/PNRR. About EUR 2 M are earmarked to support PI-to-PI collaborations during the period of the Strategic Plan (2024-2029). A key factor in the success of the RNA Technologies Program is the network of peers with whom we have collaboration agreements. They are: the National Institute of Molecular Genomics (INGM), the Human Technopole (HT), the recently created Biotechnopole in Siena, and the European Molecular Biology Laboratory (EMBL).

The RNA Technologies Program's strategic objectives are:

- Make fundamental discoveries in the biology and mechanisms of noncoding RNA;
- Understand RNA opportunities in therapy by developing novel and pathologically and anatomically relevant preclinical models for administering RNA-based medicines. Obtain at least one drug candidate based on an RNA molecule;
- Increase IIT's patent portfolio in RNA technologies and RNA therapy, potentially leading to the establishment of startups and sponsored research agreements with external companies in the field of RNA therapy.

To achieve the Program objectives, we will act in several research directions to:

- Develop robust omics technologies, including implementation of third-generation sequencing applications with nanopore;
- Characterize new RNA-based mechanisms, including RNA chemical modifications, RNA structures (e.g. circular RNAs), and artificial RNAs (e.g. aptamers). A focused investment in equipment will increase the Program's capacity to discover new mechanisms;

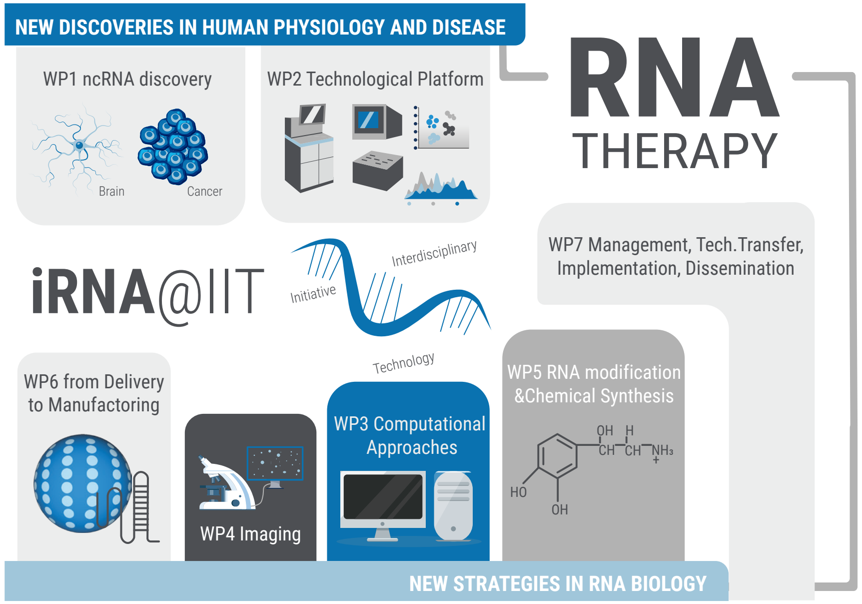


Figure 9: Representation of the aims of the RNA Technologies Program.

- Improve computational genomics and especially genomics for health (see the CMP³@VdA project), including methods for gene expression analysis, gene function prediction, and variant annotation;

- Strengthen computational biology to predict the structural properties of biologically relevant molecules and to model RNA regulation and the effect of mutations. Use AI to predict the folding properties of RNA and RNA-RNA interactomes, and molecular dynamics methods that take into account RNA modifications;

- Optimize workflows for structural biology approaches to RNA properties including Cryo-EM of protein-RNA complexes;

- Develop RNA microscopy for single-molecule approaches and RNA tracking. This builds on our solid capacity in advanced ultra-resolution microscopes and fluorescence correlation spectroscopy;

- Develop preclinical models of RNA therapeutics, such as organoids, lab-on-chip, and animal models for a staged, preclinical development of RNA-based therapeutic products. This involves refining models that recapitulate relevant patho/physiological conditions.

The expected impact of the RNA Technologies Program has two major components: 1) fundamental research on the mechanisms of action of RNA in certain cellular processes, such as those involved in cancer and neurodegeneration; and 2) translational research in RNA-based drug engineering in order to identify and target new druggable pockets of the relevant molecular components of cellular processes.

High-performance computing is an enabling element of digitalization and forms the foundation of the concept of integrated innovation.

Both components rely on IIT’s strong computational background in terms of simulations (molecular simulations) and the use of AI to model and further interpret the large amount of data generated by experiments.

Teaching Science to Computers

Molecular dynamics simulations, AI, and data science have become pillars of contemporary science. Their applications and further development are key to addressing the transition to a greener economy and the health issues of an aging population. To this end, this Flagship Program brings together PIs with domain knowledge in physics and chemistry and PIs with a strong mathematical and computer science background. Our goal is to guarantee that the deep knowledge of the problems provided by the domain experts becomes a priori information in the next generation of efficient AI methods.

IIT's total investment (see The budget of the Strategic Plan vs. the past on page 28) is around EUR 4 M/year with the contribution of 16 Research Units and Facilities and 30 researchers. In addition, the Program manages about EUR 4 M/year of EU projects and NextGenEU/PNRR. IIT has also committed about EUR 3 M to boosting AI theoretical development to be used in the next 5-6 years.

We note that IIT's investment also includes the HPC (3Pflops in 2023) and the Institute-wide storage, which are both essential to testing and developing cutting-edge solutions for data science, machine learning, and AI. In addition, IIT participates in the National Center on HPC and Quantum Computing, funded under the NextGenEU/PNRR program. IIT's budget is EUR 8.6 M.

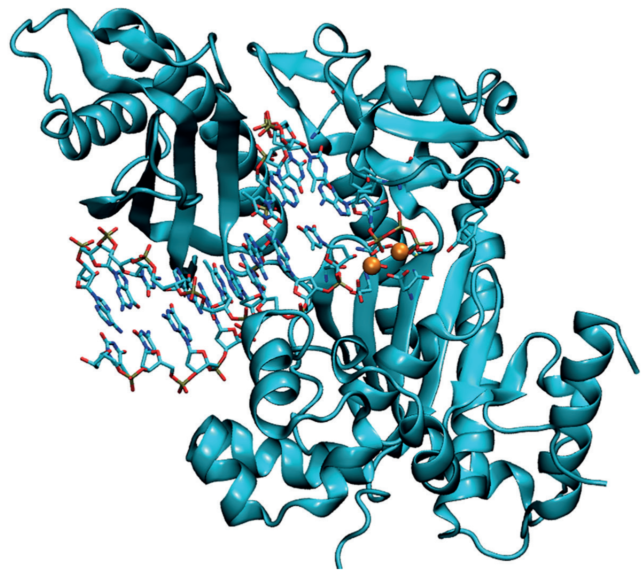
The extended partnership (called FAIR) on AI grants EUR 3.4 M to IIT's PIs. Our participation in the ELLIS European Network on machine learning is also a great benefit to the visibility of IIT's Computational Sciences Domain. Importantly, we are exploring quantum computing (QC) at the algorithmic level via the National Center infrastructure and an agreement with CERN. This important area is only accessible at the software level (hardware for QC is out of reach for IIT's finances). Because of the hardware limitations, applications of QC are still limited and typically very theoretical. We are focusing on establishing computational bounds and performance in molecular simulations.

Another subgoal of this Program is the synergistic integration of fundamental physical laws and domain knowledge with machine learning in order to solve real-life problems in chemistry and physics in the presence of missing, interspersed, scarce, or noisy data points.

Typical problems include: the analysis of the interaction of small molecules with large targets like proteins, RNA, or DNA; material properties prediction for fast development; and large-scale simulations to optimize robot design. These machine learning applications require the development of new algorithms that can work provably well, despite the complexity of the datasets. We would like the computer to understand the fundamental chemical and physical processes, surpassing black-box solutions. This will ultimately lead to the generation of improved learning algorithms capable of identifying the crucial mechanistic features of complex chemical and biological processes.

In turn, this will allow complex chemical processes to be unraveled and controlled, leading to the rational design of complex catalytic processes or the engineering of new drugs. Thus, the Teaching Science to Computers Program will also be relevant to other Flagship Programs, such as RNA Technologies.

Foundational machine learning (ML) research will lead to a new generation of improved algorithms that can seamlessly incorporate and integrate prior information about the specific problem at hand.



Massively parallel supercomputing systems can solve large-scale biological problems.

With the above goals in mind, we will focus on the following threads:

- Physics-informed ML, incorporating prior knowledge into a given ML problem in the form of mathematical equations that describe laws of nature defined by partial differential equations (PDE) or dynamical systems;

- Continual learning: studying the process of learning new tasks by leveraging existing knowledge from previous tasks and designing algorithms that accumulate knowledge to accelerate future learning;

- Large-scale ML: developing budgeted algorithmic solutions with requirements tailored to the difficulty of the problem and the quality of the data. These systems will be designed to adapt to the available computational infrastructure (from tiny to edge ML);

- Trustworthy AI: developing rigorous guarantees in terms of accuracy and computational costs, certifying that the derived models are robust to data perturbation (both stochastic and adversarial) but also model misspecifications;

- Multimodal Learning (MML) and Privileged Information: taking advantage of diverse and possibly complementary data modalities, accounting for the fact that not all information available in training will also be accessible or reliable in testing.

The main areas of research and activities are:

- Chemical and biochemical catalysis;
- Ligand design and drug discovery;
- Protein and nucleic acid structure-function relationships;
- Engineering of new biomaterials;
- Materials and nanomedicine design;
- Genomics data science and multiomics;
- Robotics and embedded systems;
- Computer vision and bioimaging;
- Systems and cognitive neuroscience;
- ML theory.

From the technical point of view, the main tools include deep neural networks in replacement of PDEs, alternative state variable representation, the approximation of quantum theory via ML methods, etc. These tools will find application in the study of proteins and nucleic acids, and thus are linked to the RNA Technologies Program. The moment is particularly ripe, given the growing amount of genomics, transcriptomics, lipidomics, proteomics, and metabolomics data, which will be used to enrich our models and domain knowledge.

Generative ML will be explored to create new molecular entities of relevance for drug and material design. Catalytic processes of industrial relevance will be part of the targeted system analysis and modeling.

Apart from its theoretical/scientific value (algorithms), the expected impact will be in understanding chemical processes like the catalytic reactions in materials and enzymes, the rational design of chemical matter with engineered features and improved performance, drug design, and engineered proteins. As noted above, the approach has already led to technology transfer with the creation of two startups (for in silico drug design and drug discovery).

Moreover, new methods for training controllers and sensory processing in difficult-to-model environments can mean the difference between success or failure in robotics. MML, continual learning, and meta-learning are clearly advantageous when designing robots to generalize across different tasks with budgeted computational resources. We will design robot controllers that mimic biological neural networks and exploit principles of neural computation. Physics-informed ML will help generate information-rich and super-resolved bioimages.

Technologies for Healthy Living

To date, an estimated 21.1% of Europe's population is more than 65 years old. This proportion is expected to increase until at least 2058, reaching 30.3%. Aging is associated with a variety of medical conditions, including neuromotor impairments, loss of muscle and bone strength, cardiovascular and metabolic diseases, cancer, and cognitive decline associated with neurodegeneration. These numbers require a caregiving reform.

The Technologies for Healthy Living Program aims to revolutionize caregiving by designing and validating tools to help frail individuals and communities maintain independence and stay healthy, thus reducing hospitalization. It also creates AI-driven environments to support continuity of care from hospital to home.

IIT's total investment (see "The budget of the Strategic Plan vs. the past" on page 44) is about EUR 5 M/year with the contribution of 28 Research Units and Facilities and about 40 researchers. The Program activities will be conducted within the framework of several National and EU funded projects, including multiple ERC StG and CoG projects, MSCA projects, EIC Pathfinder projects, NextGenEU, Horizon Europe, AIRC projects, and fellowships and support from private foundations (about EUR 10 M/year in total). About EUR 2 M are earmarked to support PI-to-PI collaborations during the period of the Strategic Plan (2024-2029).

Two classes of technologies will be designed, developed, validated, and, eventually, deployed:

- Sensors, AI, and robotic assistants, robotic companions to monitor frail individuals at home (intelligent and interactive environments);
- Activatable drug delivery systems to administer therapies on demand, at home (smart medicines).

Endowing the home with wearable point-of-care (PoC) sensors, AI, and robotic technologies will improve the daily care of frail individuals and patients with chronic diseases in the home. A healthier, active, and more independent life will be facilitated by continuous monitoring and rehabilitation, increasing social participation, and improving the quality of communication between patients, doctors, and relatives. Remote monitoring will be integrated with activatable drug delivery devices to precisely dispense therapeutic agents (small molecules, RNA, proteins, antibodies, nanoparticles) on command. Injectable and implantable nanoscale/microscale drug delivery systems will be activated by following the information collected by the sensing environment.

Robotics is transforming the field of neurological and post-traumatic rehabilitation.

Technologically, the goal is to create solutions to measure health status and deliver treatment on demand without interfering with daily life activities. This is key to healthy aging.

The Program aims to address fundamental scientific questions, such as elucidating the mechanisms underlying the interaction between humans and technologies in order to facilitate their acceptance; identifying functional and physiological biomarkers that can objectively measure the quality of life of the patient and the results of the medical intervention; and investigating new cause-effect relationships between biological and behavioral parameters and biomedical symptoms.

Our starting point is technological. Examples of technologies in our researchers' portfolio include: noninvasive PoC diagnostics; computer vision to monitor behavior; edible sensors; and digital twins to analyze the motor, cognitive, sensory, and overall physiological state of the patient. The Program's drug delivery component will deploy technologies to enable treatment on demand based on information collected by the sensing environment.

Data will be made available to clinicians for diagnosis. Control systems, starting from the sensory data, can elaborate appropriate interaction with the subject and enact assistance. In this context, the Program will develop wearable sensors, activatable drug delivery devices, smart interactive systems such as robotic agents, intelligent stations, tools for navigation and disorientation reduction, robot-assisted or music-based rehabilitation protocols to assist an individual in the execution of activities of daily living, training, rehabilitation, or communication with care givers.

The Program will also Investigate the synergy between an individual and the smart environment, such as the dynamics of interaction, social attunement between the patient and their robot companions, and saliency detection.

Several of these technological components have a high technology readiness level (TRL). Industrial property is also protected by patenting components in the early stage of development. The numerous opportunities for technology transfer include: prostheses, PoC devices, sensors, and drug delivery devices, which are either ready for commercialization to reach their intended patient groups, or are undergoing different levels of clinical/preclinical validation.

Using results from the Joint Lab between INAIL and IIT, Technologies for Healthy Living can pursue several avenues to reach the market. These include licensing, further Joint Labs with companies, and incorporation of start-ups. A start-up to commercialize our prostheses (e.g. hand, elbow, ankle) or small home robotic devices is also conceivable. In addition, the studies on human-machine interaction and the application of on-demand drug delivery will contribute to the success of the Brain and Machines and the RNA Technologies Flagship Programs.

Appendix 2: Infrastructure & Centers

IIT's infrastructure comprises the Central Laboratories in Genoa and the Network Centers. The total size of the laboratories is about 50,000 m^2.

The Network Centers were created to connect IIT with some of the best minds in Italian academia, to complement our strategic development, and to capitalize on Italy's excellent research centers.

Main entrance of the Center for Convergent Technologies in Genoa.

For the Centers' future development, the general strategic goals are:

- Guaranteeing the medium-to-long-term sustainability of the Centers in terms of size (i.e. critical mass of scientists), local networking (both scientific and technology transfer), and financial support (regional and external funding, etc.);

- Guaranteeing high-quality infrastructure and location of all Centers as well as the available laboratory equipment.

As part of the infrastructural evolution, this Strategic Plan defines several practical general principles to drive our actions:

- Initiate an extensive search for better locations and laboratory space, particularly in order to strengthen scientific or technological collaborations where common objectives with the co-located parties can be established;

- Maintain a coherent thematic structure and unitary vision of the Centers, and where necessary, create further coherence with targeted hirings. The Centers should avoid isolation and maintain both a continuous connection with the Central Laboratories and with the academic or nonacademic local partners;

- Reduce the number of Centers and favor economy of scale whenever strategically aligned with IIT's overall scientific and technology transfer vision;

- Create institutional Joint Labs in lieu of the more complicated Center structure to seize specific collaboration opportunities, such as establishing IIT's presence in other countries.

Any action in this sense is extensively validated institutionally by the STC in its periodic assessment of the state of the Network Centers.

Internally, we are investing in and better organizing the shared Facilities. With the increased number of PIs, IIT must further plan and regulate access to the important (and most expensive) laboratories.

There are 18 shared Facilities in Genoa and 11 infrastructural laboratories in the Network Centers. The Facilities are organized and supervised by Research Domain as follows:

- Robotics: Mechanical Workshop, Electronic Design Laboratory, Advanced Robotics, iCub Technology, Industrial Robotics;
- Nanomaterials: Material Characterization, Electron Microscopy, Clean Room, Chemistry, Material Technologies for Industry;
- Life Technologies: Animal Facility, Neurofacility, Genomics, Translational Pharmacology;
- Computational Sciences: Data Science and Computation (read HPC), Analytical Chemistry, Structural Biophysics, Medicinal Chemistry and Technologies for Drug Discovery and Delivery.

The Center for Human Technologies (CHT) research activities are focused on technologies for human health, rehabilitation, and human-machine interaction.

Moreover, institute-wide digital storage (10 PB in total) was installed at the end of 2022. In addition to the HPC, this is a fundamental asset in the increasingly data-driven research foreseen by this Strategic Plan. All laboratories will require important digitalization to structure data acquisition, streamline storage, and organize data[19] to allow a better use of data for advanced statistics and AI methods. In preparation for this digital transition, a complete mapping of all instruments and their readiness level has begun. Software systems will also be mapped and organized as they become crucial to an efficient digital transition (software standardization and internal reuse). This mapping will become part of the internal specifications for software development and conservation.

As certain infrastructure, such as a quantum computer, is beyond reach, we will maintain a parsimonious approach by seeking agreements to access new and expensive pieces of technology. In this context, the NextGenEU/PNRR National Centers will play a role in providing access to certain infrastructure. We will also pursue federated endeavors to share large equipment e.g. EU infrastructural programs[20].

The second major infrastructural transition is related to energy efficiency and sustainability. The analysis has begun and will indicate how to achieve the European Green Deal targets by having 55% of IIT's energy use come from renewable sources by 2030. IIT's actions will include better buildings, better behaviors, and better energy sourcing. This must happen while maintaining our scientific and technical performance (see also "Appendix 6: Sustainable energy" on page 69).
The Technologies for Sustainability Program (described in Section Technologies for Sustainability) will also use all of IIT's infrastructure as a living lab to test and perfect some of our own solutions to the challenge of taking care of our planet.

The third major infrastructural overhaul of this Strategic Plan is related to healthcare, specifically, to the Erzelli Center for Computational and Technological Medicine in Genoa . The Erzelli hospital is one of the Italian Flagship projects covered by the Ministry of Health and the NextGenEU programs. Because of our experience with designing and realizing the Center for Human Technologies (CHT, also in Genoa) and CMP^{3}VdA (5000 genomes) in Valle d'Aosta, IIT was tasked with contributing to the design of about 20,000 m^2 of laboratory space. We aim to design a first-in-human laboratory, in which to develop precision medicine (as per the RNA Program), neuroscience (as per the Brain and Machines Program), and technology-driven rehabilitation (as per the Technologies for Healthy Living Program).

19 Data should be FAIR (Findable, Accessible, Interoperable, Reusable).

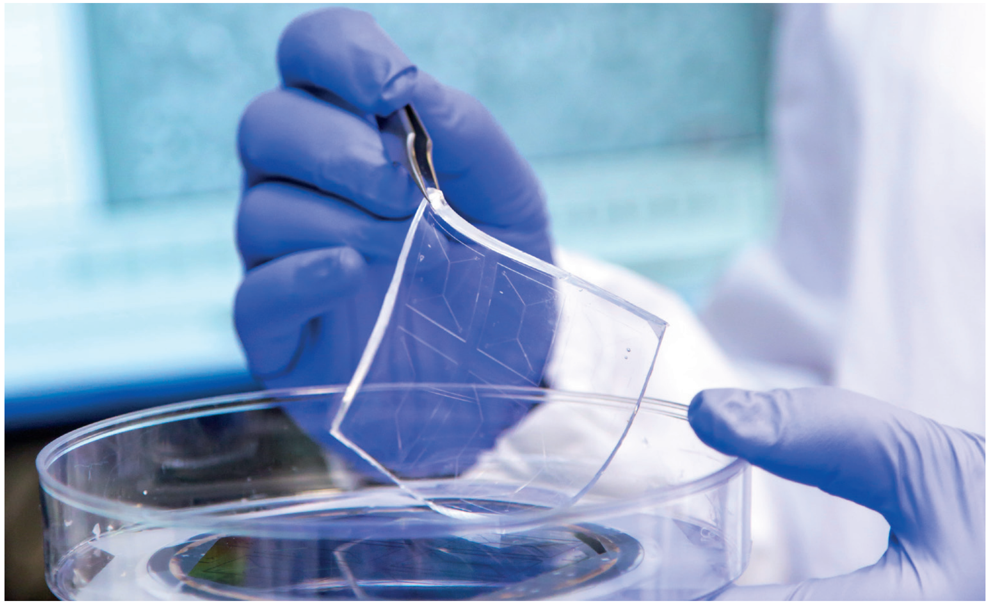
20 For example: IIT coordinates the Eurobench project (https://eurobench2020.eu) and is a partner for the Euro Bioimaging project (https://www.eurobioimaging.eu).

Appendix 3: The Technology Platform

Well-equipped laboratories are one of IIT's main assets. The digital aspect notwithstanding, laboratory experiments must eventually be conducted.

In fact, the quality of laboratory equipment is part of IIT's attractiveness. However, laboratories require continuous maintenance and upgrades to remain at the state of the art. Therefore, part of our Strategic Plan addresses investment in equipment.

IIT has progressively committed an increasing level of resources to maintaining and expanding the Facilities. This clear strategy will remain valid for the duration of this Strategic Plan.



Each IIT facility offers researchers and students a wide range of services, from essential routine to more advanced technical and consulting services.

The current count of the Facilities include:

Computational: high-performance computing (HPC), software installation and optimization for parallel architectures, AI/simulative software development.

LifeTech: advanced animal models and support for animal experiments , multi-omics analytics (MS, NMR, sequencing, single-cell profiling), multimodal imaging, structural and biophysical characterization, synthetic and medicinal chemistry, chemical biology, neurobiology, biochemical and cellular assays, full genomics and transcriptomics, short and long reads analysis. The observation of the cell is complemented by optical nanoscopy expertise.

Nanomaterials: design of function through nanofabrication, device-oriented prototyping, synthesis of nano(composite/structured) materials, state-of-the-art characterization of materials properties (from example through X-ray diffraction, electron microscopy, spectroscopy, surface analysis).

Robotics: virtual prototyping and simulations, electronic and mechatronic design, software and firmware development, CNC machining, additive manufacturing, precompliance EMC tests.

As mentioned earlier, automation and AI are accelerating research in nanomaterials. IIT will establish an Automated Synthesis Lab to focus on producing nanomaterials (organic, inorganic, hybrids) via systematic experimental design and execution using automated instrumentation, while collecting and integrating data that are ready for AI and ML.

The laboratory will support explorations of a wide range of materials phenomena at nanoscale by providing automated paths to synthesis (see Figure 10).

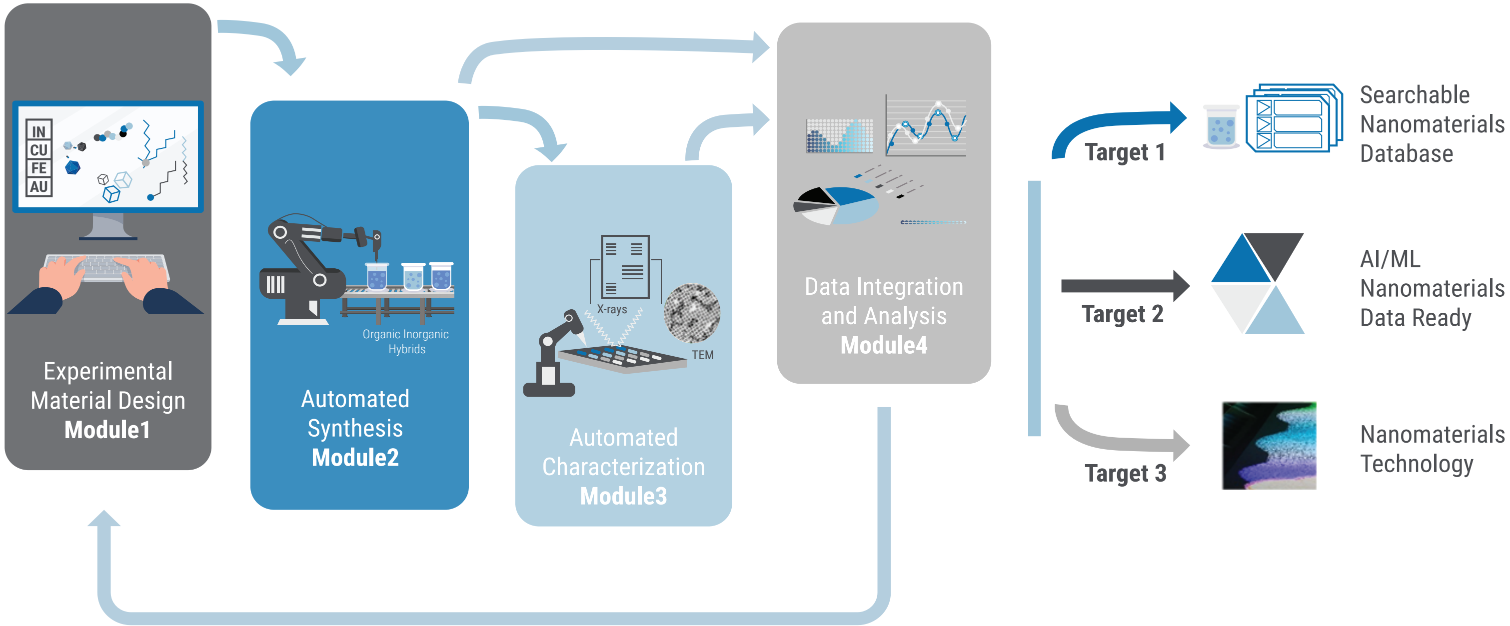


Figure 10: Envisioned workflow of the Automated Synthesis Lab at IIT. The Lab is based on four interactive modules: experimental material design (module 1), automated synthesis (module 2), and automated characterization (module 3), which will enrich module 4 dedicated to collecting data for integration and analysis. This innovative hardware and software infrastructure will aim to continuously feed a searchable nanomaterials database (target 1), and produce FAIR data for AI/ML (target 2), and it will promote the seeding of startups and patents in nanomaterials technology (target 3).

Appendix 4: A brief history of IIT

The Istituto Italiano di Tecnologia (IIT) is a Private Foundation, established by the State at the end of September 2003, and regulated by article 14 et seq. of the Italian Civil Code.

IIT is predominantly financed by the State with the goal of stimulating technological development, technological training, and higher education, in line with Italy's scientific and technological agenda. IIT's ultimate objective is to foster the innovation and competitiveness of Italy's production system.

IIT develops a program of basic and applied research with the aim of transferring research results to industry for commercial exploitation and to healthcare institutions to improve the wellbeing of society.

The Center for Convergent Technologies (CCT) is the largest research infrastructure in the IIT network and is where the Foundation started its activity in 2006.

IIT's activities include the development of scientific capacity, the construction and maintenance of state-of-the-art research laboratories, the development of excellent practices and positive competition, training and higher education at the postgraduate level, the creation of programs to attract talent, and the broad dissemination of knowledge and scientific results.

IIT operates in four broad scientific areas, which we call Research Domains (RDs): Robotics, Nanomaterials, Technologies for Life Science, and Computational Sciences, with a distinctive multidisciplinary approach to the pursuit of excellence.

Since its establishment, IIT's driving force has been the development of new knowledge and its translation into concrete applications in a fully interdisciplinary approach. With its first strategic plan, the Humanoid Technology Program (2009-2011), IIT introduced the concept of bioinspired intelligent machines to support humans in everyday life.

This concept brought together disciplines such as neuroscience, nanotechnology, and mechatronics, which had often barely communicated with each other.

The 2012-2014 plan expanded this interdisciplinary vision by introducing the concept of Translating Evolution into Technology, i.e. systematically mimicking natural systems to develop new technologies in the fields of robotics, materials science, and life science.

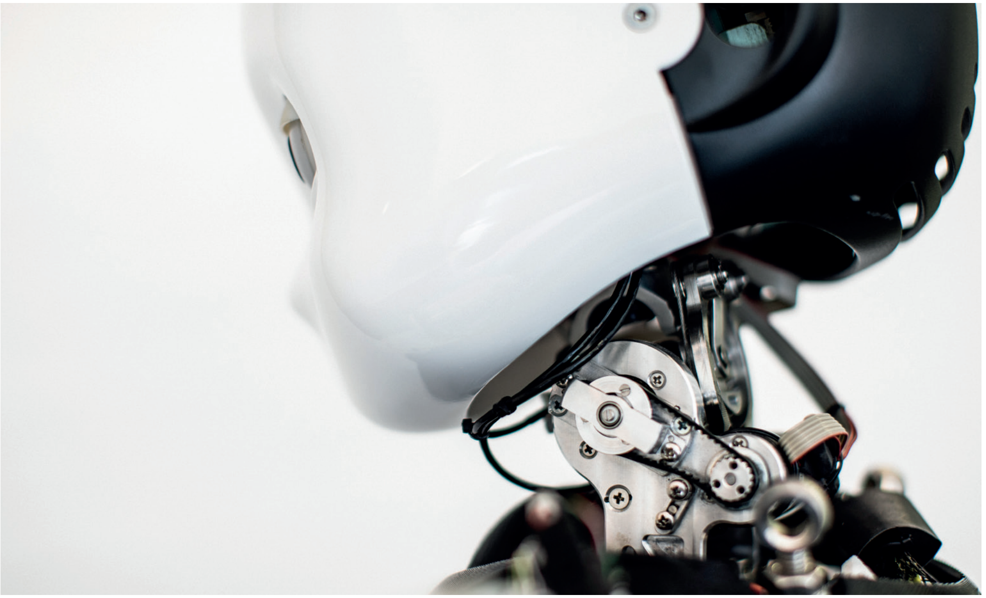
This created the knowledge basis for the strategic plan of 2015-2017: an interdisciplinary research program centered on the Human Being. In accordance with this plan, IIT started to apply different bioinspired technologies to healthcare, sustainability, and personal assistance.

The 2018-2023 Strategic Plan revolved around Human-Centered Science and Technologies. More specifically, in the first three years (2018-2020) the newly defined RDs were established and consolidated, while several infrastructural upgrades were completed, including the genomic facility in the new Center for Human Technologies, the high-performance computing cluster for atomistic and molecular simulation and artificial intelligence and machine learning research, and the new extreme conditions laboratory to support nanomaterials research (see "Assessing the past and present" on page 14).

Today, the new 2024-2029 Strategic Plan primarily recognizes the importance of the digital transition and, especially, of AI, which is impacting traditional experimental disciplines at all levels.

The centrality of the human is still a fundamental element in our research, while sustainability and healthcare are even more urgent today than six years ago. To address these challenges, we need to change how we conduct research.

We need to recognize the value of experimental data and extract their maximum value through an intense use of AI. If we do not recognize that science itself is evolving, we may fail our mission. We would simply be too slow to compete in the international arena of science and technology.



In 2007, IIT entered the iCub project with a dedicated fully equipped laboratory for iCub research network and is where the Foundation started its activity in 2006.

Twenty years after its creation and seventeen years after the inauguration of the headquarters in Genoa, IIT is starting its third decade of activity with a solid critical mass of infrastructure, people, and skills. As of 2024, the Institute comprises five large laboratories in Genoa (see Appendix 2: Infrastructure & Centers), 11 Centers forming a network of labs across Italy, and two outstations (Joint Labs) in the USA (Boston area), for a total of more than 50,000 m^2 of laboratory space.

IIT's staff comprises about 1900 people from 70 countries with an average age of 36 years.

Among IIT staff, there are 23 different scientific profiles from medicine to engineering, and 80 PIs, including 32 ERC winners. In terms of gender, IIT is 43% (female) to 57% (male). A strong diversity and inclusion program was launched in 2019 with the creation of the Diversity and Inclusion Office. A Gender Equality Plan was officially adopted in 2021 and is updated yearly.

IIT staff have generated about 18,000 scientific publications, carried out more than 900 industrial projects, 28 Joint Labs with companies and/or research institutions, 385 European projects, 33 startups (with several more business ideas in development), and about 1300 patents.

We are highly motivated, enthusiastic, skilled, and mostly young researchers, technicians, administrators, and support staff who work every day for humanity's common good.

Appendix 5: Data Management

Following European guidelines and inspired by values of transparency and efficiency, IIT recognizes the importance of managing research data responsibly and, whenever possible, openly, by applying cutting-edge research data management (RDM) practices. RDM's purpose is to ensure reliability and reproducibility, but also to enable new and innovative research built on existing information.

Since 2018, IIT has invested in improving RDM services to support scientists throughout the research cycle. IIT has supported Open Science practices to promote the dissemination of results and increase knowledge transfer. Dissemination of scientific results has a clear social and educational value. All these actions were developed in line with the three Os (Open Science, Open Innovation, Open to the World), which were identified as core values to pursue in the previous Strategic Plan (2018-2023).

In this framework, IIT has been developing infrastructures to enable big data storage, high-performance computing (HPC), and preservation and open sharing of research data.

An effective RDM can create direct bridges between scientists and stakeholders.

Since 2021, IIT has activated an open-source institutional repository to describe datasets with standard and rich metadata, preserving and sharing them following the European philosophy of "as open as possible, as closed as necessary". Very recently, IIT deployed a new enterprise-level on-premises storage infrastructure, comprising 10 PB of usable storage space decentralized across 14 IIT centers with centralized monitoring and management of data, metadata, and security. This infrastructure will significantly increase IIT's storage capacity and will serve as the main container of curated and reusable datasets. Moreover, the integration of HPC facilities and storage will enable further development of high-performance data analytics applications.

IIT has adopted the FAIR data management principles. FAIR stands for Findable, Accessible, Interoperable, and Reusable, and inherently emphasizes machine-actionability (i.e. the capacity of computational systems to find, access, interoperate, and reuse data with no or minimal human intervention), including the possibility of applying AI approaches.

Action plan

1. Infrastructure by providing seamlessly integrated services and tools that researchers will use to store, organize, transfer, analyze, preserve, share, and re-use FAIR research data;
2. Policies to set objectives and provide guidance on the production of FAIR-by-design data;
3. Human resources by integrating a (new) skilled workforce of IT and data professionals to support scientists.

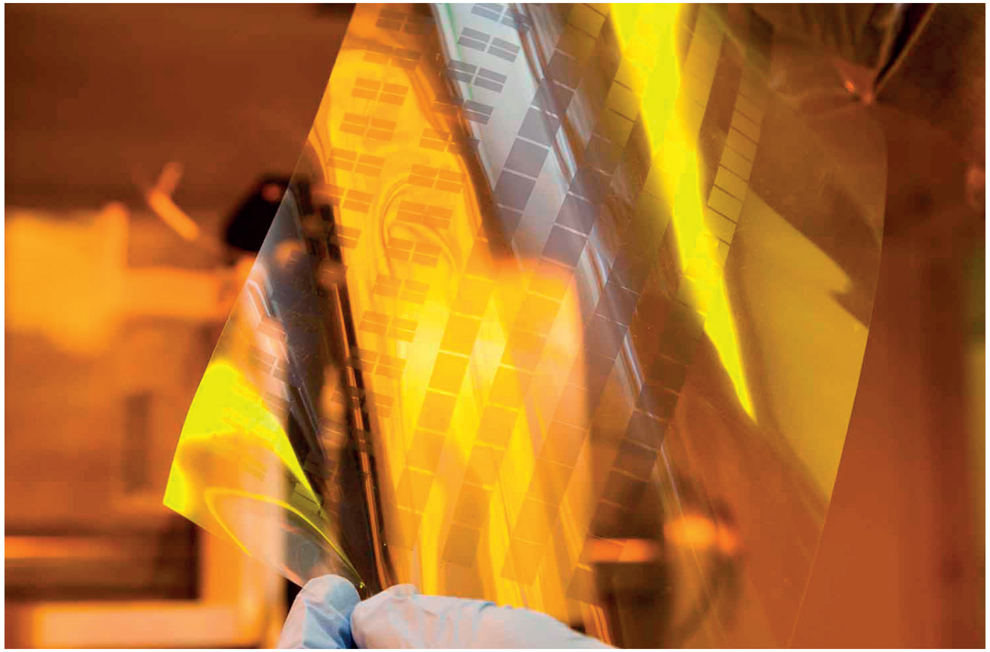
Appendix 6: Sustainable energy

The 2022 energy shock and the current international (UN Agenda 2030), European (EU Green Deal, REPowerEU), and national policies (Fit for 55) require IIT to shift towards a safe and more environmentally friendly energy system.

As part of this Strategic Plan, we therefore set the target of making IIT 55% green by 2030.

IIT's infrastructure runs 24/7. It is particularly demanding in terms of energy: local temperature, humidity, and air quality in the laboratories often require precise control. The clean room, the animal facility , temperature-controlled spaces, refrigerators, and the HPC are examples of our most energy-intensive laboratories and facilities.

The net yearly consumption of electricity is 11GWh. The gas consumption is about 500,000 SCM per year.



Printed organic electronics is a future-oriented environmentally friendly green technology with potential applications in micropower generation.

Our action plan for energy thus includes:

- Increase use of efficient technology: thermal isolation of buildings, latest generation of boilers;
- Renewable sources: installation of photovoltaic solutions on or off premises, creation of a local energy community;
- Redefine purchasing strategies and services: adopt policies to support green purchasing (IIT received a special prize in the 2023 Compraverde national award);
- Reduce waste: increase campaigns for energy saving and waste reduction, additional certifications (beyond the ISO14001:2015)

Investment is planned to achieve the sustainable energy goals as shown in the section The budget of "The budget of the Strategic Plan vs. the past" on page 44.

IIT's total investment in infrastructure quality will be about EUR 37.5 M, including a direct investment of EUR 13 M in energy efficiency.

Appendix 7: Glossary

AIRC: the Italian Association for Cancer Research. An Italian foundation that runs a cancer research program with grants and fellowships.

Artificial Intelligence (AI): AI is a subfield of computer science that develops algorithms to perform some of the tasks of the human or animal brain. Examples of these tasks are movement control, formal reasoning, game playing, image recognition, speech recognition, and language generation.

CAGR: Compound aggregated growth ratio.

Earthcare: the care of the planet and the environment. Achieving sustainability is form of earthcare.

EIC: European Innovation Council. Part of the European Horizon framework program funded by the EU Commission, the EIC is Europe's flagship innovation program for identifying, developing and scale up breakthrough technologies and game-changing innovations.

EIC Pathfinder: one of the EIC's funding schemes (project type).

ERC: European Research Council. Part of the Horizon framework program of the EU Commission, the ERC is the premier European funding organization for excellent frontier research. It funds creative researchers of any nationality and age to run projects across Europe.

ERC CoG: the ERC Consolidator Grant for scientists of medium seniority (typically more than 8 years after receiving their PhD).

ERC StG: the ERC Starting Grant for scientists with 2-7 years of experience after receiving their PhD.

ESG: Environmental, Social, and Corporate Governance. This framework is used to assess an organization's business practices and performance on various issues related to sustainability and ethics. It is normally embedded in an organization's strategic vision.

FAIR data (Findable, Accessible, Interoperable, and Reusable): data which meet principles of findability, accessibility, interoperability, and reusability. The FAIR principles emphasize machine-actionability (i.e., the capacity of computational systems to find, access, interoperate, and reuse data with none or minimal human intervention).

Flagship Programs: well-defined and visionary research activities with a broad scope and a time horizon of 6 years. They are subject to evaluation according to standard IIT procedures. They are meant to structure technical projects, create critical mass, increase IIT's visibility in a specific field, attract talented researchers, and build complementary and integrated expertise.

Fondazione Istituto Italiano di Tecnologia (IIT): abbreviation IIT, in English "Italian Institute of Technology" or "Italian Institute of Technology Foundation". For indexing purposes, the Italian version is used in official publications.

HPC: High-Performance Computing. Computer architectures for special high-end computation typically designed by combining a multiplicity of microprocessors and their connectivity in order to maximize their combined throughput.

Industrial Liaison Program (ILP): a program designed to provide regulated access to IIT's intellectual property in return for fees.

Joint Laboratory (JL): a contractual agreement with a third party to develop a joint research program, typically with a medium-term vision (multi-annual) and alignment with IIT's Strategic Plan. The contribution is typically 50:50 but other allocations are possible.

Machine Learning (ML): ML is an area of AI concerned with designing algorithms that learn a required behavior directly from data with potentially minimal human intervention. The designer defines how the task is learned, while the task specifications are automatically derived from data.

MSCA: Marie Sklodowska-Curie Actions. A European Horizon grant that supports early career development of scientists.

NextGenEU (NGEU): the Next Generation EU recovery program set up after the Covid-19 pandemic. The Italian program is also called PNRR (National Program of Recovery and Resilience).

PNRR: see NextGenEU.

Principal Investigator (PI): a (typically) senior researcher/scientist at IIT. A PI conducts research by independently directing a Unit. A PI's general goals are to excel in scientific research and technology transfer. Each PI acts independently in terms of (and is accountable for) research and budget strategies within the boundaries of IIT's Strategic Plan and overall monetary allocation.

Research Domain (RD): a broad disciplinary area of IIT's research. There are four RDs: Robotics, Nanomaterials, Life Technologies, Computational Sciences.

Ribonucleic Acid (RNA): polymeric molecule essential for most biological functions, either by performing the function itself (non-coding RNA) or by forming a template for the production of proteins (messenger RNA).

Scientific Initiatives: grassroot interdisciplinary research programs introduced in the interim update of the 2018-2023 Strategic Plan. The interim update was agreed in 2020. The Scientific Initiatives are now superseded by the Flagship Programs defined above.

Sustainable Development Goals (SDGs): SDGs are a set of goals defined by the UN as part of the 2030 agenda for sustainable development[22]. They address topics such as energy and water, economic development, reduction of poverty and hunger, the right to healthcare and education.

Tenure: completing the Tenure Track process leads to a tenured (indefinite) position. PIs are also said to have received tenure.

Tenure Track (TTr): the process of becoming a permanent member of the IIT faculty. The Tenure Track starts with an entry evaluation, continues with an intermediate promotion, and it is completed with the final tenured evaluation that grants tenure.

TRL: Technology Readiness Level. A simple scale of the readiness of technology with respect to its application in marketable products[23].

Unit: a research group managed by a PI comprising younger researchers, postdocs, students, and collaborators. A typical Unit includes office and laboratory space.

22 https://sdgs.un.org/goals.

23 https://bit.ly/3IKqfpu.

Acknowledgments

I'd like to thank all Principal Investigators who actively participated in the writing of this Strategic Plan, a work that, overall, has been more than a year in the making. Particularly, I want to thank our Associate Directors, Facility Coordinators and Administrative Directors for the specific contribution each one of them delivered.

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IIT Scientific Director
Giorgio Metta

Figures

Tables

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