

ENAC Self-Assessment Report 2019

VOLUME A





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Cover Photo: Celebrating ENAC's winning entry in the 2017 Solar Decathlon Competition.

Foreword

I am proud to present the Audit documentation on behalf of the ENAC community.

ENAC is a diverse academic enterprise, situated within a leading institute of engineering and technology, dedicated to understanding and improving our built and natural environments. The challenges that accompany our changing world are more and more evident, a situation that only serves to underscore ENAC's raison d'être. Its grouping of Architecture, Civil and Environmental Engineering brings together the relevant technical and scientific disciplines to anticipate and tackle these changes and humanity's role in them, sustainably and responsibly. Importantly for the challenges we face, this grouping also welcomes the corresponding academic and professional cultures and intellectual traditions, and provides the milieu in which they can thrive. ENAC has a rich tradition of diverse and impactful activities in research, education and innovation, a sample of which can be found within the Audit documentation. The continued enhancement of this tradition is of fundamental importance to the future vitality of ENAC.

D. Andrew Barry
ENAC Dean a.i.

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Table of Contents

1. INTRODUCTION	1		
1.1 ETH Domain	1		
1.2 EPFL's Organization	2		
1.3 Short History of ENAC	3		
1.4 Follow-up of ENAC Evaluation 2011 and Midterm Review 2014	4		
2. SCHOOL OF ARCHITECTURE, CIVIL AND ENVIRONMENTAL ENGINEERING (ENAC)	5		
2.1 Vision, Mission and Strategy	5		
2.1.1 ENAC Vision	5		
2.1.2 Research	6		
2.1.2.1 Antennas and Institutes	8		
2.1.3 Education	10		
2.1.4 Innovation	11		
2.2 Reputation	11		
2.3 Organization	13		
2.4 Funding	14		
2.5 Interdisciplinary Collaboration	16		
2.5.1 Collaboration within ENAC	16		
2.5.1.1 Smart Living Lab (SLL, EPFL Fribourg)	17		
2.5.1.2 Alpine and Polar Environment Research Center (ALPOLE, EPFL Valais, Sion)	19		
2.5.2 ENAC Extended Community	19		
2.5.3 Collaboration with other EPFL Laboratories and Beyond	20		
2.5.3.1 Transportation Center (TRACE)	20		
2.5.3.2 Habitat Research Center (HRC)	21		
2.5.3.3 Energy Center (CEN)	22		
2.5.3.4 Limnology Center (LIMNC)	23		
2.5.3.5 Cooperation and Development Center (CODEV)	25		
2.5.3.6 Swiss Polar Institute (SPI)	25		
2.5.3.7 Collaborations Outside EPFL	27		
3. FACULTY	28		
3.1 Overview	28		
3.2 Recruitment and Promotions	29		
3.2.1 Faculty Recruitment Strategy	29		
3.2.2 Recruitment Process	29		
3.2.3 Promotion Process	30		
3.2.4 Hires and Promotions Since 2011	31		
3.2.5 Future Faculty Retirements	33		
3.2.6 Proposal for <i>Professors of Practice</i>	34		
3.3 Junior Faculty Mentoring and Integration	35		
3.4 Promotion of Gender Equality	36		
4. EDUCATION	37		
4.1 Overview	37		
4.2 Bachelor and Master Programs	37		
4.2.1 Background	37		
4.2.1.1 Interdisciplinary Courses, Projects, Contests, Entrepreneurial Spirit	38		
4.2.1.2 Accreditation and Rankings	38		
4.2.2 Architecture	39		
4.2.2.1 Introduction and Objectives	39		
4.2.2.2 Curriculum	44		
4.2.2.3 Quality of the Program	45		
4.2.2.4 Teaching Resources	46		
4.2.2.5 Anticipated Curriculum Evolution	47		
4.2.3 Civil Engineering	47		
4.2.3.1 Introduction and Objectives	47		
4.2.3.2 Curriculum	50		
4.2.3.3 Quality of the Program	51		
4.2.3.4 Teaching Resources	51		
4.2.3.5 Anticipated Curriculum Evolution	52		
4.2.4 Environmental Sciences and Engineering	52		
4.2.4.1 Introduction and Objectives	52		
4.2.4.2 Curriculum	54		
4.2.4.3 Quality of the Program	57		
4.2.4.4 Teaching Resources	57		
4.2.4.5 Anticipated Curriculum Evolution	58		
4.2.5 Student Statistics and Alumni Survey	63		
4.3 Doctoral Programs	63		
4.3.1 Overview	66		
4.3.2 Civil and Environmental Engineering (EDCE)	67		
4.3.3 Architecture and Sciences of the City (EDAR)	68		
4.3.4 Mechanics (EDME)	69		
4.3.5 Robotics, Control, and Intelligent Systems (EDRS)	72		
4.4 Interdisciplinary Education and Teaching Innovation	72		
4.4.1 Design Together Program	72		
4.4.1.1 Vision	72		
4.4.1.2 History	72		
4.4.1.3 Program Structure	73		
4.4.1.4 Learning Approach	74		
4.4.1.5 Program Level Offers	75		
4.4.2 Solar Decathlon	76		
4.4.2.1 Student Experience	76		
4.4.2.2 Swiss Living Challenge Project	77		
4.4.2.3 Objectives and Outcomes	77		
4.4.3 SKIL – Student Creativity and Innovation Laboratory	77		
4.4.3.1 Infrastructure	77		

4.4.3.2	Pedagogical Framework	78	5.4.6	Inter- and Multidisciplinary Collaboration	106
4.4.3.3	After One Year...	79	5.4.7	Outlook and Perspectives	107
4.4.3.4	Outlook	79	5.5 Shared Scientific Infrastructure	108	
4.5 Continuing Education		80	5.5.1	ENAC Interdisciplinary Platform for X-ray Micro-tomography (PIXE)	108
4.5.1	Master of Advanced Studies in Urban Planning and Design	81	5.5.2	Central Environmental Laboratory (GR-CEL)	110
4.5.2	Certificate of Open Studies: Management and Planning of African Cities	81	5.5.3	Structural Engineering Platform of the Civil Engineering Institute (GIS Laboratory)	111
5. RESEARCH		82	5.5.4	Platform of Hydraulic Constructions of the Civil Engineering Institute (PL-LCH)	112
5.1	Overview	82	6. INNOVATION, TECHNOLOGY TRANSFER & PUBLIC OUTREACH	114	
5.2	Institute of Architecture and the City (IA)	83	6.1	Overview	114
5.2.1	Overview	83	6.2	EPFL Support for Technology Transfer and Innovation	114
5.2.2	Personnel	83	6.2.1	Vice Presidency of Innovation and Technology Transfer Office	114
5.2.3	Research Portfolio	84	6.2.2	Transportation Center (TRACE)	115
5.2.3.1	Theory and History	84	6.3 ENAC Programs for Innovation and Tech Transfer	115	
5.2.3.2	Construction and Sustainable Development	84	6.3.1	InnoSeed ENAC Program	115
5.2.3.3	Art and Expression	85	6.3.2	Industry Liaison Officer	117
5.2.3.4	Territory and Society	85	6.4 Partnerships with Industry	118	
5.2.3.5	Project and Design	85	6.4.1	Research Agreements with Industry	118
5.2.4	Scientific Output and Scholarly Impact	86	6.4.2	Framework Agreements and Funded Chairs	119
5.2.5	Inter- and Multidisciplinary Collaboration	87	6.5 Technology Transfer to Industry and Public Sector	119	
5.2.6	Vision	87	6.5.1	Start-ups Emerging from ENAC Laboratories	119
5.2.7	Outlook and Perspectives	89	6.5.2	The Smart Living Lab as Hub for Innovation and Technology Transfer	121
5.3 Civil Engineering Institute (IIC)		90	6.5.3	Swiss Competence Centers for Energy Research (SCCER)	122
5.3.1	Overview	90	6.5.4	Knowledge and Technology Transfer through Professional Practice and Project Work	122
5.3.2	Personnel	90	6.5.5	Contributions to Civil Engineering Standards	123
5.3.3	Vision	91	6.5.6	Policy Advice to Governmental Bodies	123
5.3.4	Research Portfolio	92	6.5.7	Contributions to Capacity Building in the Global South	124
5.3.4.1	Structures and Materials	92	6.6 Patents, Licenses & Open Science Research Products used in Industry	124	
5.3.4.2	Transportation and Networks	93	6.7 Collaboration and Exchange with Industry as Part of Education	127	
5.3.4.3	Geosystems and Natural Resources	94	6.8 Knowledge Transfer to the Society at Large	127	
5.3.5	Scientific Output and Scholarly Impact	95	6.8.1	Outreach Events	128
5.3.6	Inter- and Multidisciplinarity	96	6.8.2	ENAC in the News	128
5.3.7	Outlook and Perspectives	96	6.8.3	ENAC and Social Media	129
5.4 Environmental Engineering Institute (IIE)		98	6.8.4	ENAC and EPFL Annual Reports	129
5.4.1	Overview	98	6.8.5	Exhibitions	129
5.4.2	Personnel	99	6.8.6	Citizen Science	129
5.4.3	Research Portfolio	99	6.9 Conclusions and Outlook	130	
5.4.3.1	Atmosphere and Climate	100	ANNEX	131	
5.4.3.2	Ecology and Biogeochemical Cycles	100			
5.4.3.3	Environmental Modeling and Monitoring	100			
5.4.3.4	Human-Environment Interactions	101			
5.4.3.5	Water and Waste Engineering	101			
5.4.3.6	ALPOLE – Alpine and Polar Research	102			
5.4.4	Vision	102			
5.4.5	Scientific Output and Scholarly Impact	105			

1. Introduction

EPFL is part of the ETH Domain, which is mandated to improve Switzerland's competitive through its activities in education, research and technology transfer.¹

1.1 ETH Domain

The ETH Domain comprises the two Federal Institutes of Technology in Lausanne (EPFL) and Zürich (ETHZ), as well as the four autonomous research institutes: the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Science and Technology (Empa), and the Swiss Federal Institute of Aquatic Science and Technology (Eawag). With its numerous locations, the ETH Domain is firmly rooted in the Swiss regions.² The ETH Board (ETH Domain strategic management body) and the ETH Internal Appeals Commission (independent appeals body) also belong to the ETH Domain.

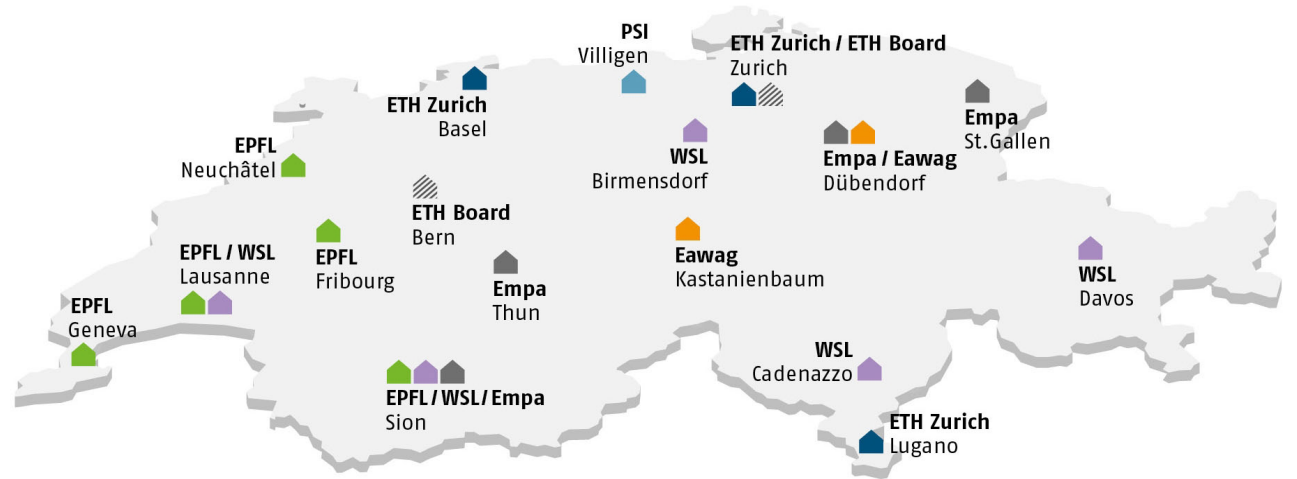


Figure 1.1. Locations of ETH Domain entities.

The ETH Act defines the purpose of the two Federal Institutes of Technology and the four research institutes as follows:

- To educate students and qualified staff in scientific and technical fields and to provide continuing education
- To expand scientific findings through research
- To foster upcoming young scientists
- To render scientific and technical services
- To perform public relations activities
- To exploit research findings

¹ https://www.ethrat.ch/sites/default/files/ETH_Bereich_in_Kuerze_EN_Web_180523.pdf

² <https://www.ethrat.ch/en/eth-domain/overview>

1.2 EPFL's Organization

EPFL received the status of a national school in 1969, and therefore celebrates its 50th anniversary in 2019¹ Since then, it has developed on many levels, to the point of becoming one of the most renowned science and technology institutions in Europe. Like ETHZ, it focuses on three core missions: education, research and innovation.

The EPFL ethos is characterized by dynamism and curiosity. Daily exchanges between students, researchers and entrepreneurs on campus encourage the emergence of new scientific, technological and architectural projects.

The main EPFL campus is located in Lausanne, on the shores of the largest lake in western Europe, Lake Geneva (lac Léman), at the foot of the Alps and Mont Blanc. EPFL is structured into five Faculties (Schools):

- School of Architecture, Civil and Environmental Engineering ([ENAC](#))
- School of Basic Sciences ([SB](#))
- School of Engineering ([STI](#))
- School of Computer and Communication Sciences ([IC](#))
- School of Life Sciences ([SV](#))

and three (smaller) Colleges:

- College of Management of Technology ([CDM](#))
- College of Humanities ([CDH](#))
- Middle East College ([ME](#))

EPFL is present in five Swiss cantons: Vaud, Geneva, Valais, Fribourg and Neuchâtel. While teaching activities physically take place on the main Lausanne campus, research groups are located at all EPFL sites, with concentrations in Geneva, Sion, Fribourg and Neuchâtel. ENAC is a core participant in the Fribourg Smart Living Lab, created in 2014. At Sion, in the Canton of Valais, ENAC is developing another strong presence with the creation of the ALPOLE Center (section 2.5.1.2), to start in 2019.

EPFL's main campus brings together more than 15,000 people, including more than 11,000 students, nearly 350 professors and over 6,000 scientific, administrative and technical collaborators². Of these, ENAC includes 2,238 students, 61 professors and 732 collaborators.

¹ <https://www.epfl.ch/campus/events/celebration-en/>

² <https://www.epfl.ch/about/overview/overview/figures/>

1.3 Short History of ENAC

The School of Architecture, Civil and Environmental Engineering at EPFL (Faculté de l'environnement naturel, architectural et construit, ENAC) was formed in 2002 to bring together the fields necessary to address open questions of sustainability in the built and natural environments. A central theme of ENAC, which has been pursued since its inception, is to carry out research that provides new knowledge essential to professions and to educate new generations of leaders in engineering and architecture who are able to successfully enter directly into professional practice or to progress into academic or scientific careers.

Initially, the School was organized into five research Institutes and three teaching programs (Sections). After the first academic evaluation in 2006, the number of Institutes was reduced to four. Following the 2011 academic evaluation, the Institutes were reorganized into three balanced pillars, with corresponding teaching programs. This occurred by removal of a transversal Institute (called INTER). Laboratories that

constituted INTER joined either the Institute of Architecture or the Institute of Civil Engineering. Both Institutes were significantly reinforced as a result.

The composition of the ENAC Direction (senior management team) follows this organization, and comprises the Dean, the three Institute Directors and the three Section (teaching program) Directors.

The first Dean (2002-2008) was Prof. Laurent Vulliet, expert in soil mechanics and presently a professor in ENAC. The second Dean was Prof. Marc Parlange (2008-2013), expert in environmental fluid mechanics and presently Provost and Senior Vice President of Monash University. He was succeeded by Prof. Marilyn Andersen (2013-2018), expert in daylighting and sustainable construction technologies and presently a professor in ENAC. Prof. D. Andrew Barry, expert in environmental engineering, is the ad interim Dean since September 2018.



1.4 Follow-up of ENAC Evaluation 2011 and Midterm Review 2014

The insightful report from the 2011 Audit Committee highlighted different areas of ENAC's strengths, as well as recommendations for its evolution. The recommendations articulated in the Audit Committee's report are listed in the Annex, along with the ENAC responses shortly after the Audit as well as further responses given in the follow-up midterm review in 2014. The main points are presented below.

The panel reported that ENAC had significantly transformed itself over the preceding five years (since the 2006 Audit), and noted the following major achievements:

- **Research** – A significant overall advance in research productivity marked by increased scholarly output (leading archival journals, monographs and texts) and the level of research support.
- **PhD Programs** – ENAC contributed to and participated in new doctoral schools (EDCE and EDME), emphasizing student applicant quality, efficient and effective operations and an active program of student-organized events in a stimulating research environment.
- **New Faculty** – Recruitment of high caliber faculty, with an emphasis on Tenure-Track Professors in addition to notable senior and mid-career appointments. Faculty members were well supported by excellent resources (facilities, equipment funding and opportunities to recruit high quality research staff and students), working within a supportive collegial environment.
- **ETH Domain Interactions** – Productive collaborations within the ETH Domain (notably Eawag, WSL, PSI and Empa), mainly through joint appointments.
- **Facilities** – Excellent research facilities within ENAC and EPFL. The internal organization of platforms supporting teaching and research was particularly well received.

The Audit Committee noted different areas for future enhancement, which are paraphrased (along with very brief responses) as:

- **Effectiveness of the ENAC Concept** – ENAC is complex and diverse, bringing together scientists, engineers, architects and social scientists. The concept is important but more needs to be done to achieve its potential, e.g., through internal collaborations. Response: ENAC proposed a range of measures aimed at academic excellence, from faculty and student recruitment to measures aimed at improving opportunities for internal interdisciplinary teaching and research.
- **Strategy** – The detailed strategic plans of the Institutes did not translate well to a clear ENAC strategy, with goals and prioritized actions. Response: The strategy involved different aspects, e.g., improving energy-related research, developing expertise in urban systems engineering (as a unifying element) and strengthening the PhD program in Architecture and Sciences of the City.
- **Education** – Interdisciplinary education across ENAC is a core aspect of the ENAC vision, however further improvements were recommended, e.g., in planning and evaluation of the relevant courses. Response: Urban sciences, and in particular a program in urban systems engineering was to be developed.
- **Gender Balance** – Improvements in gender balance, principally through tenure-track appointments, were recognized, with the recognition that this effort should continue. Response: More efforts in recruitment and conditions of women faculty.

2. School of Architecture, Civil and Environmental Engineering (ENAC)

2.1 Vision, Mission and Strategy

2.1.1 ENAC Vision

ENAC was created as EPFL's dedicated environment-facing faculty. Its vision is to leverage EPFL's positioning as a cutting-edge school of technology to develop scientific understanding of the numerous environmental and societal challenges humanity faces, to find new ways to adapt to them, and to equip future generations with knowledge and skills to guide the developments to come.

The well-documented, rapid changes to our planet's environment engender myriad challenges, with ramifications that will become increasingly evident for at least the rest of this century. The underlying causes of these changes are greenhouse gas emissions and human encroachment, both of which are predicted to increase despite the widespread recognition of their impacts. These impacts are particularly evident in land-locked Switzerland, with its rich endowment in ecological diversity and water resources, its significant agriculture and forestry sectors, its reliance on hydropower, its widespread and small-scale communities, and its mountainous terrain. In Switzerland (and elsewhere), issues such as infrastructure replacement (e.g., wastewater treatment plants) and urban sprawl (with its effects on natural resources) must be treated holistically with recognition of the numerous impacts and factors at play. In recognition of these circumstances, EPFL has put sustainability as a core part of its mission, a mission that ENAC will continue to embrace through its leadership in discovering new scientific insights, its development and utilization of technologies, and its contributions to policies and strategies for a more sustainable future.

As an example of climate change effects, the Swiss situation, which is of central importance to ENAC, can be considered. Average temperatures will rise, with expected summer average temperature increases typically estimated in the range of 2-4°C, depending on emissions. This is in addition to an estimated 2°C increase in the past 150 years. Annual precipitation across Switzerland shows little change, although the frequency of intense precipitation has increased, with further increases expected. Besides precipitation, expected trends are for drier and hotter summers, much-reduced winter snowfall and continuing glacier retreat.

The effects of climate change, in Switzerland and elsewhere, lead to concomitant changes in environmen-

tal functioning, desertification, stressed ecosystems/lost biodiversity and decreased ecosystem services. In addition, human encroachment and its associated environmental footprint exacerbate these changes, with accompanying pollution/wastes, and loss of habitat due to urbanization.

ENAC is well placed to address these challenges. Its composition, which brings together architecture with civil and environmental engineering, is rarely found worldwide. Yet, it is precisely this emphasis on the built and natural environments that equips ENAC in its mission to confront major challenges, both present and foreseen. The significant resources and modern infrastructure available to ENAC enable broad and deep initiatives. With the large number of retirements across the faculty in the coming decade (section 3.2.5), ENAC has a major opportunity to build upon its current internationally recognized position and contribute to these upcoming challenges. Realization of this renewal opportunity will rely on a vigorous, ongoing faculty recruitment program that will strengthen ENAC's leadership in its chosen research fields, and meet social expectations in terms of education of future generations of competent professionals in architecture, civil and environmental engineering. In both research and education, ENAC will use its position in a leading polytechnical university to leverage and contribute to technological innovations and knowledge transfer. That is, ENAC's strategy is shaped to continue fulfilling the three EPFL missions, in terms of cutting-edge research and high-level education of our future engineers/architects and opportunities for technology transfer through innovation.

Different thematic foci will characterize ENAC's research and teaching efforts in the coming years, in several cases continuing efforts that have built momentum since the last audit, as described below.

2.1.2 Research

Research, centered within ENAC's three Institutes, is diversified both in terms of topics and scientific approaches. ENAC has established scientific leadership in several key research fields such as transportation and mobility, hydrology and water resources, and environmental sensing and modeling. More generally, ENAC's research profile is very appropriate for tackling major environmental issues facing society at present.

Different research themes will guide ENAC's future research agenda, as it positions itself to address different issues in sustainability, environmental changes and societal impacts, as described above. A pervasive feature that is embedded in all research themes is digitization, which creates numerous new opportunities to explore questions and design solutions. Specific (and partially overlapping) thematic areas of interest include:

- **Energy** – Energy use is central to many aspects of society and its impact on the environment, and is the subject of research across EPFL (see Energy Center, section 2.5.3.3). ENAC will continue to contribute to the development and evaluation of distributed energy sources (hydropower, geothermal, photovoltaic installations), efficient energy use in buildings and construction as well as to the deeply required social transformations (behavioral change, governance of decentralized energy systems). In transport, automation, energy efficiency (electrification) and multi-modality are fundamental, and are researched within the TRACE center (section 6.2.2).
- **Integrative and Computational Approaches** – ENAC will strengthen computational and integrative approaches in the built and natural environments. Civil engineers and architects will reinvent their way of addressing construction, from conceptualization to realization, for instance with the availability of a multiplicity of environmental and material parameters utilized integratively in the development process. Across ENAC, digitalization will continue to be integrated at the practice and at the academic levels. These competences are critical in civil engineering where practice will increasingly rely on engineers with mastery in numerical modeling and data analysis skills. Likewise, architectural practice will move increasingly towards seamless incorporation of digital tools into design and realization. Environmental engineering and science will use real-time, widespread data to support environmental monitoring and regulation, to constrain multiscale models and to inform environmental policy.
- **Building on Big Data** – In all ENAC domains, the continued generation and availability of big data is certain to advance. For instance, the generation of large datasets from next-generation sensors will be commonplace. Their analysis requires innovative modeling tools, computation and synthesis frameworks in environmental, civil and building engineering. Thus, ENAC will build on and expand its ability to synthesize the foreseen wealth of data, using new models and theories that connect ongoing and future research, generating new understanding of natural and built environments from large to small scales. For instance, ENAC researchers have already produced key developments through the integration of big data with models of transportation networks, e.g., in understanding of mobility patterns, logistics optimization and smart infrastructure for the travel of people and goods.
- **Climate Change Impacts and Adaptation** – Numerous ENAC laboratories investigate climate change or address issues directly related to it. As a defining issue for the foreseeable future, climate change will receive increasing attention within ENAC in the coming years. Clearly, this theme overlaps other ENAC themes. For instance, throughout society, energy efficiency must remain a focus (e.g., in building functioning and transport systems). In urban settings, mitigation of the heat-island effect requires different strategies (e.g., neighborhood design, urban water availability) to maintain comfort of inhabitants. Resource and material needs, ecosystem services, environmental pollution, greenhouse gas emissions, etc. all should be understood at a system level in order to anticipate and mitigate climate change impacts.
- **Urbanization** – Urbanization spurs a unique set of challenges for ENAC. Not surprisingly, it is a longstanding ENAC focus, and it will remain so. Globally some of the most pressing problems facing the environment come from the evolving dynamics of urbanization. ENAC will leverage its ability to think across scales (multi-scalar) and disciplines (architecture, civil and environmental engineering), and its savviness with new technologies (e.g., smart sensors, field robotics, spatial data visualization, digital modeling and design) to address the complex and systemic challenges of urbanization related to changes in land-use, inhabitation patterns, air pollution, water availability, waste disposal, social flows, and urban economics, which are exacerbated by the augmenting population density and the requirements of urban concentration.

Based on the above themes, ENAC will pursue the following strategic areas to guide its development:

- **Sustainable Adaptation to Climate Change** – The cumulative impacts of environmental stressors, as starkly manifested at high latitudes and elevations, are increasingly evident at all scales and locales. ENAC will evaluate and predict changes to the natural environment (e.g., hydrological and biogeochemical cycles, ecosystem services). Adaptation strategies to climate change impacts, already part of the fabric of ENAC's research profile, will be further emphasized as an explicit cross-faculty theme, permeating research and education at all levels.
- **Technology Development and Integration** – ENAC will pursue a continuous strategy of transversal technology utilization and innovation across all aspects of its research and education, based on recognition of technology as a mediator between humanity and the built and natural environments, wherein it guides a new cultural dimension for understanding our environment and our relationship with it. A particular interest is the use of technologies for improving sustainability, resource use efficiency and risk assessment, e.g., construction methods based on automated, bespoke design, operational 'prosumer' buildings (produce and consume resources and energy), and technology-aware transportation infrastructure. A common theme will be adaptable multiscale sensing deployed and integrated in the natural and built environments.
- **Sustainable Urbanization** – A key strategic axis will focus on sustainable urbanization. ENAC will expand its current research and teaching initiatives to confront the complex challenges of urbanization, and push further the development of cross-disciplinary research platforms, such as the Habitat Research Center (HRC), Smart Living Lab (SLL), and TRACE. The strategy will be founded on an exploration of urbanization phenomena based on aggregating architects, urbanists, civil and environmental engineers, urban ecologists and social scientists. The HRC explores ecological, technological and social transitions, promoting a future-oriented and interdisciplinary design approach as a core research tool. The SLL serves as hub for innovation and technology transfer for research on technical, societal, and economic challenges of the built environment, and is paving the way to more efficient systems and healthier, more comfortable and more personalized built environments. The Transportation Center (TRACE) acts as the interface between EPFL and the outside world for all matters related to transportation and mobility, of both people and goods. ENAC will extend its sustainable urbanization efforts to include: smart/resilient cities and communities, efficient use of energy and resources, and decentralized renewables and energy systems.

ENAC envisages the following specific actions to realize these strategic interests:

- **Building Critical Mass in Climate Change** – ENAC will expand its climate change research via collaboration with the Faculty of Geosciences and Environment (FGSE) of the University of Lausanne (situated adjacent to the EPFL main campus at Lausanne). FGSE offers complementary research expertise to ENAC in different areas of the natural and social sciences. ENAC will explore the feasibility of forming a partnership with FGSE to address climate change impacts in natural and social systems, for instance understanding changes in hydrological and biogeochemical cycles, designing transport solutions under modified weather patterns, socially-inclusive decision-making and sustainable urban planning.
- **Wastewater Treatment and Water Technology** – Many Swiss water treatment plants will be upgraded up until 2040, with an investment of CHF1 billion. In collaboration with Eawag, whose mission includes this area, ENAC will renew its academic programs (e.g., by new joint ENAC-Eawag professors) to maximize the return on this investment by investigating novel water treatment technologies and processes, by creating innovative solutions, and by forming engineers with advanced training and competences in this area.
- **Technology Synergies** – EPFL is richly endowed with technology-related expertise in areas such as image and signal processing, robotics, machine learning, data analysis and large-scale computing. There is much potential to stimulate new research avenues and to promote translational research in a wide variety of contexts. This will be achieved by partnering of ENAC with other faculties in EPFL, using measures such as joint research projects or cross-faculty professorships. In parallel, ENAC's education programs will equip students with skill sets that enable them to create and take advantage of both hardware and software to innovate novel solutions.

- Sustainable Urbanism – Urban systems are innately human-centered, but involve ecological, technological and social transitions. Such systems, present a major challenge to the very notion of sustainability, given their resource consuming/waste producing characteristics. ENAC will further strengthen its profile with a new laboratory focusing on sustainable urban metabolism (example keywords: circular economy, life cycle analysis, distributed energy systems and networks, ecological footprint, material flow analysis).

2.1.2.1 Antennas and Institutes

ENAC's contributions in research are based on its antennas and Institutes. ENAC has in place two antennas, at Fribourg and Sion, that will act as foci some for elements of the above-mentioned themes and strategic directions, since they each provide the critical mass necessary for impactful research the built and natural environments, respectively. At Fribourg, the Smart Living Lab (section 2.5.1.1), a multi-institutional team consisting of 11 research groups, focuses on efficiency in building processes and technology, human well-being in indoor settings, energy systems and integrated design processes. At Sion, in the Canton of Valais, ENAC's nascent Alpine and Polar Environment Research Center (ALPOLE, section 5.4.3.6), will research changes taking place in high-altitude and high-latitude environments with the appointment of a group of five integrated professorships.

The *Institute of Architecture and the City* (IA) will maintain and reinforce its distinctive position in the architectural academic environment – that of a research body reflecting a cultural pedigree linking building activity with humanities, social sciences and experimental sciences. Today, the pillars of this edifice are to be found in the five areas of concentration of the Institute:

- Theory and History
- Construction and Sustainable Development
- Art and Expression
- Territory and Society
- Projects and Design

New appointments to be made in the next two years – in Projects and Design and in Theory and History – will be critical in spearheading a process of further dialectical integration between the five areas, hence consolidating the profile of Architecture at ENAC as a set of complementary 'savoirs', grounded in theory as well as in practice. This is done with a view to building exponential capacity in the disciplinary undertaking of ever-growing multi-dimensional design challenges, where it is difficult to separate environment and economy, institutions and building fabric, technology and cultural mores. It is expected that the type of technical humanism championed by the Institute will become a signifier of disciplinary currency and evolutionary lead, exemplified by emerging research structures (such as the Smart Living Lab in Fribourg) as well as the increasing number of design-based collaborations with the professional, industrial and institutio-

nal world in the gateways of Lausanne and Geneva but also in Europe.

The *Institute of Civil Engineering* (IIC) is currently building a long-term strategy for the development of the institute. As part of its underlying principles, the focus is to identify the challenges of modern civil engineering during the next 10-20 years, as well as the research questions that will have a strong impact on the discipline and the society. The most important of them is sustainability, which has the objective to perform activities without any reduction of resources or impacting the environment negatively.

Research contributions to sustainable civil engineering involves fundamental decision-making models and methods, assessment of natural hazards, construction technologies, and materials, demountable infrastructure and risk assessment, with an emphasis on multi-disciplinary approaches. Recent technological and methodological developments provide new opportunities to address civil engineering challenges, such as robotics, smart monitoring, large-scale optimization, numerical modeling, 3D printing, and augmented humans. In particular, the pervasiveness of data and artificial intelligence is provides crucial opportunities to address these challenges. These developments should be properly coupled with fundamental knowledge and civil engineering principles. The strategy thus aims to emphasize the importance of these methodologies.

From a more operational standpoint, IIC will need to ensure a smooth transition given the upcoming retirement wave. Future recruitments will be organized at a regular pace, to maximize the probability of attracting outstanding new colleagues, and to improve the Institute age pyramid in the long term. Current recruitments in hydraulic infrastructure and transportation networks will ensure a strong impetus for this development. Cross-fertilization with other ENAC Institutes will be pursued as part of IIC's strategy, which is already underway with the creation of the Smart Living Lab. With hydraulic structures, IIC will address new challenges that have arisen during the last decades, such as sustainable use of water, optimization and restoration of large hydraulic facilities, risks, resilience and vulnerability of water systems, conservation and restoration of natural habitats, energy conversion, and computational tools for managing water resources and systems. In several of these areas, fruitful interactions with IIE are foreseen.

The *Institute of Environmental Engineering* (IIE) bases its future research profile upon broad methodological expertise in field and laboratory experimentation, modern technologies for environmental monitoring and simulation, and the assessment of impacts of environmental processes and environmental policies. This will facilitate its contributions to different research domains, as follows:

- The Alpine and Polar Environment Research Center (ALPOLE) center will provide leadership in multiscale understanding of climate change effects on frozen water resources and downstream impacts on water cycles, extreme events, ecosystem services, etc.
- Systems-oriented approaches will be used to assess changes to ecosystems and human health, to identify causes and effects of environmental pollution, and to develop strategies for sustainable resource development. Scientific understanding of natural and human-impacted systems, an established research focus in IIE, will underpin research into the changing environment.
- IIE will continue to develop novel environmental technologies and monitoring tools, by leveraging the outstanding technical expertise available within EPFL. In conjunction with the ready availability of data, and the Institute's existing and incoming expertise (new hire in ALPOLE) in simulation and modeling, will create new understanding and solutions across multiple scales.
- An area that is foreseen to grow is human-environment interactions, within the context of environmental change. Effects on human society on ecosystems, and vice versa, must be quantified and managed in policy settings. The increasing availability of big environmental data (for example with respect to emissions, air quality and human health) will allow for new approaches to analyze human-environment interactions in quantitative ways, and to determine the impacts of environmental policies. These interactions as they relate to urbanism, building, and energy use will be an area of growth in IIE, and will involve collaborations with the other ENAC Institutes.

2.1.3 Education

The specificities of ENAC give a particular context to its strategy. Education, which is responsive to industry needs, has a very important professionalizing characteristic. ENAC has large student numbers with high graduate employment rates, who have important influences on the economy, industry and public policy in a variety of areas (e.g., infrastructure, services, environmental monitoring). Its vision is to educate students so that they develop deep technical knowledge and understanding, strength in cooperating across fields and in professional life – in short, a broad capacity to address a range of changing environmental challenges having different scientific, technological, social, economic and legal dimensions.

Bachelor/Master level education in ENAC is organized into three teaching Sections, Architecture, Civil Engineering and Environmental Sciences and Engineering. PhD programs are organized separately, as described below.

The key role of the *Architecture Section* ([SAR](#)) is to educate future architects with a solid polytechnic background. Our program implants a vision embracing both the contemporary realities of architecture and its ancient roots, within a polytechnic culture where the discipline is seen as an art and a craft to be practiced with experience drawn from many spheres of scientific knowledge. The program is founded on three main pillars: (i) using and experimenting with construction techniques; (ii) learning history and theory; and (iii) acquiring an expressive individual consciousness in line with collective needs and aspirations. These approaches cut across every architecture project and carry the core of commitments and interests of all teaching programs. The program is attractive, with steadily growing student numbers (doubling since 2000), as it addresses major contemporary issues: sustainable urban development, husbanding of materials, simplification of techniques, interaction between traditional know-how and advanced technology, social compatibility, and, in general, intelligent use of resources.

The *Civil Engineering Section* ([SGC](#)) targets the education of highly qualified civil engineers able to confront the great challenges associated with the complex development of our territory. EPFL teaching in civil engineering aims for excellence in educating students capable of developing innovative solutions to the various areas of civil construction, infrastructure and mobility. The program is well regarded internationally. Its Bachelor cursus relies on a strong polytechnic education and its Master level on the option to specialize in geotechnics, hydraulics and energy, transport and mobility or structural engineering. In the future, a strengthening of the program in the areas of energy exploitation and infrastructure is planned, with an increased emphasis on transferable

skills in data sciences and information modeling. Student numbers increased by a factor two since the early 2000s, peaking in 2013.

In recent years, the program in *Environmental Sciences and Engineering* ([SSIE](#)) has been challenged by competition with Environmental Science Bachelor/Master programs offered by most universities, in a traditionally more open educational profile than Civil Engineering and Architecture. This situation reinforces the positioning of EPFL environmental engineering as distinct from environmental science elsewhere. Benchmarking and enquiries with alumni and with the advisory board have led to a more precise definition of our educational profile. That implies at Bachelor level a stronger focus on basic sciences (mathematics, physics, chemistry, biology), engineering sciences (dynamic systems control, modeling), environmental sciences, and a significant reinforcement of our students' computational competences (computational thinking, programming, algorithmic problem solving). At the Master level, a background to all tracks is taught through our core block, and openings to specializations are given through our elective specializations and minors, in consideration of both the program's engineering profile and our research foci. The Section attracts a satisfying share of new Bachelor students (89 in Fall 2017). From a teaching perspective, the recruitments of new professors planned by IIE should meet the most important needs. In the coming years, SSIE has opportunities to create distinctive teaching elements at both the Master and Bachelor levels. With the creation of the Alpine and Polar Environment Research Center (ALPOLE) at Sion, there will be sufficient breadth and depth in cryospheric science and engineering to deliver a new Master specialization in this domain. This will be explored as the new faculty members are appointed. Slightly longer term, an appointment in the area of Environmental Technologies will build upon the SKIL initiative and strengthen the Bachelor program in mechatronics/sensing/robotics. This will extend the present offering in dynamical systems control, and further emphasize the distinctly EPFL identity of the Environmental Engineering program.

Doctoral education at EPFL is organized into specialized programs. Within ENAC, the main programs are *Civil and Environmental Engineering* (EDCE) and *Architecture and Sciences of the City* (EDAR), although PhD students are affiliated with several other doctoral programs in addition. In general, the doctoral programs have focused on improving the quality of accepted students, better communication within and recognition of their respective communities, and providing more opportunities for students with, e.g., outgoing travel to other laboratories.

2.1.4 Innovation

ENAC is naturally positioned to connect research with society. Its research fields are intrinsically relevant to the environmental and societal challenges of highest importance today. The Technology transfer at ENAC has thus a pivotal significance in creating innovative products and services that meet societal concerns. ENAC has set up a specific in-

ternal program to foster innovation and support researchers in bridging the gap to the market. In line with this initiative, the recruited researchers have to demonstrate pioneering work that has the potential to produce innovative solutions to social, environmental and technical issues.

2.2 Reputation

Through its rigorous educational programs and interdisciplinary research, ENAC is a leader in development of new engineering and architectural science that provides innovative solutions for the built and natural environments, with influence in Switzerland and throughout the world. In the 50 years since its creation, EPFL has maintained its youthful ethos, with a dynamic environment that attracts outstanding undergraduates from Switzerland and throughout Europe, graduate students from around the world and international top-tier faculty members. This has bolstered EPFL's reputation and led to high international rankings.

The graduates of ENAC contribute to society broadly and hold positions of leadership in academia, government, engineering, urban planning and architectural practice. ENAC is particularly attractive as an open academic program with a vibrant atmosphere for collaboration across disciplines. Its academic reputation is enhanced by its outstanding faculty who actively seek and are open to new connections with colleagues within and outside their School. The pressing challenges facing society in urban environments require interdisciplinary approaches, and the spirit and broad academic subjects of study in ENAC are ideal for major advances in all essential domains of inquiry. Certainly, its open intellectual environment, its diversity and depth in teaching and research,

and the important role it plays in Switzerland and internationally distinguish ENAC as a leader in its chosen areas of activity, including structural engineering and mechanics, transportation engineering, geoengineering, water resources and hydrology, fluid mechanics, water and waste treatment, environmental chemistry and microbiology, renewable energy (particularly hydroelectric and wind), sustainable architecture and building physics, theory and history in architecture, urban planning and design, complex architectural design, housing and densification.

Over the past decade, ENAC researchers were distinguished by several ERC grants (Table 2.1). These highly competitive grants are awarded by the European Research Council (ERC), whose mission is "to encourage the highest quality research in Europe through competitive funding and to support investigator-driven frontier research across all fields, on the basis of scientific excellence."¹ There are different grant types (Starting, Consolidator, Advanced) corresponding to different career stages, providing funding from €1.5 mio (Starting Grants, for early-career researchers 2-7 years after PhD) up to €2.5 mio (Advanced Grants, for established research leaders) for 5 years.

¹<https://erc.europa.eu/about-erc/mission>

Table 2.1. ENAC researchers who received an ERC grant.

PI	PROJECT TITLE	GRANT
Roberto Gargiani (IA)	The surfaces of cement and reinforced concrete. A history of the formworks and processing of the surface, 1870-2008	Advanced Grant (2009 - 2015)
Andrea Rinaldo (IIE)	River networks as ecological corridors for biodiversity, populations and waterborne disease	Advanced Grant (2009 - 2013)
Anders Meibom (IIE)	Carbonate biomineralization in the marine environment: Paleo-climate proxies and the origin of vital effects	Advanced Grant (2010 - 2015)
Jean-François Molinari (IIC)	Uncovering the origins of friction	Starting Grant (2009 - 2014)
Nikolaos Geroliminis (IIC)	Modeling and controlling traffic congestion and propagation in large-scale urban multimodal networks	Starting Grant (2014 - 2019)
Rizlan Bernier-Latmani (IIE)	Uranium isotope fractionation: A novel biosignature to identify microbial metabolism on early Earth	Consolidator Grant (2017 - 2022)
Marie Violay (IIC)	Mechanical behavior of fluid-induced earthquakes	Starting Grant (2018 - 2023)
Lyesse Laloui (IIC)	Bio-mediated geomaterial strengthening for engineering applications	Advanced Grant (2018 - 2023)
Anders Meibom (IIE)	Ultimate paleo-ocean records from biogenic calcites	Advanced Grant (2019 - 2023)

With respect to well-known international University rankings published by different organizations, ENAC-relevant subjects are well positioned. They reached top-twenty to top-forty world ranks in the [ARWU Global Ranking of Academic Subjects 2018](#) – Civil Engineering (34), Environmental Engineering (33), Transportation Science and Technology (30), Water Resources (19) – as well as in the [QS World University Ranking by Subject 2019](#) – Architecture/Built Environment (12), Civil and Structural Engineering (11), and Environmental Sciences (26).

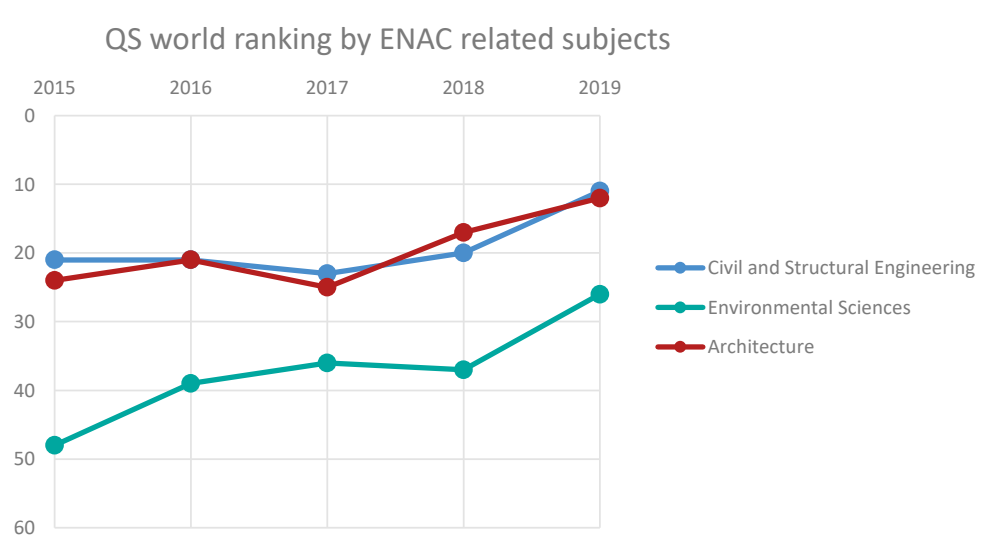
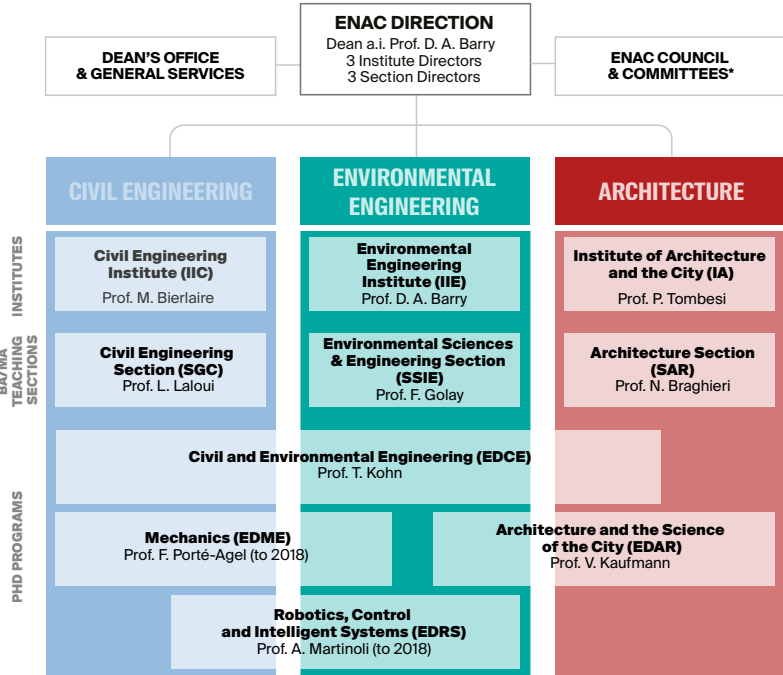


Figure 2.1. QS World rankings of ENAC disciplines since 2015.

Scientific expertise of ENAC researchers is often requested by local newspapers, radio, and television. Moreover, ENAC's research is frequently highlighted in national media and regularly reaches international level with appearances in the newspapers from abroad (section 6.8.2).

2.3 Organization



*ENAC Committees: Academic Evaluation Committee, Professors' Conference, General Assembly, Gender Equality Working Group, Professional Associations

Figure 2.2. Schematic of ENAC's management structure. Note that PhD programs are transversal to ENAC and other EPFL Faculties.

The School of Architecture, Civil and Environmental Engineering (ENAC), is structured into three research Institutes (Architecture and the City, [IA](#), Civil Engineering, [IIC](#), Environmental Engineering, [IIE](#)), each headed by an Institute Director, and three Bachelor/Master teaching programs (called Sections, Architecture, [SAR](#), Civil Engineering, [SGC](#), Environmental Sciences and Engineering, [SSIE](#)), headed by Section Directors. Doctoral education and continuing education are formally under the responsibility of the Vice President for Education, Prof. Pierre Vandergheynst. ENAC PhD students

mainly enroll in four Doctoral Programs: Civil and Environmental Engineering ([EDCE](#)), Architecture and Sciences of the City ([EDAR](#)), Mechanics ([EDME](#)), and Robotics, Control, and Intelligent Systems ([EDRS](#)). These four programs currently host 93% of all doctoral students of ENAC and have been directed by ENAC faculty now and in recent years (section 4.3).

The ENAC Direction is responsible for the School's strategy to accomplish its missions.¹ It is composed of the Dean and the Institute and Section Directors:

- The Section Directors guarantee the consistency, quality and specificity of their Sections' curriculum. They manage all academic matters related to their Section.
- The Institute Directors represent their Institute within ENAC, EPFL and the outside world. They are in particular responsible for establishing the research strategy for their Institute and for scientific, infrastructure and administrative matters as well as human resource issues regarding personnel attached to their Institute.
- The Dean bears the overall responsibility for ENAC, answers to the EPFL Senior Management for all matters relating to ENAC, and interfaces on behalf of ENAC at many levels both internally to EPFL and externally.

¹https://polylex.epfl.ch/wp-content/uploads/2019/01/LEX-1.2.9_EN.pdf

2.4 Funding

ENAC receives an annual (internal) budget from EPFL. In addition to this, it obtains funding from third parties (external) for an additional CHF20 mio. The third party fund share represents approximately 25% of the total ENAC expenses. The internal budget increased modestly until 2017 to reach its peak. Therefore, ENAC also focuses on third party funds

to maintain a constant development. In 2018, ENAC received CHF23 mio, which is its top performance. Historically, the SNSF is a major contributor of ENAC research projects (CHF8 mio in 2018). The share of EU funding also slightly increased in 2018.

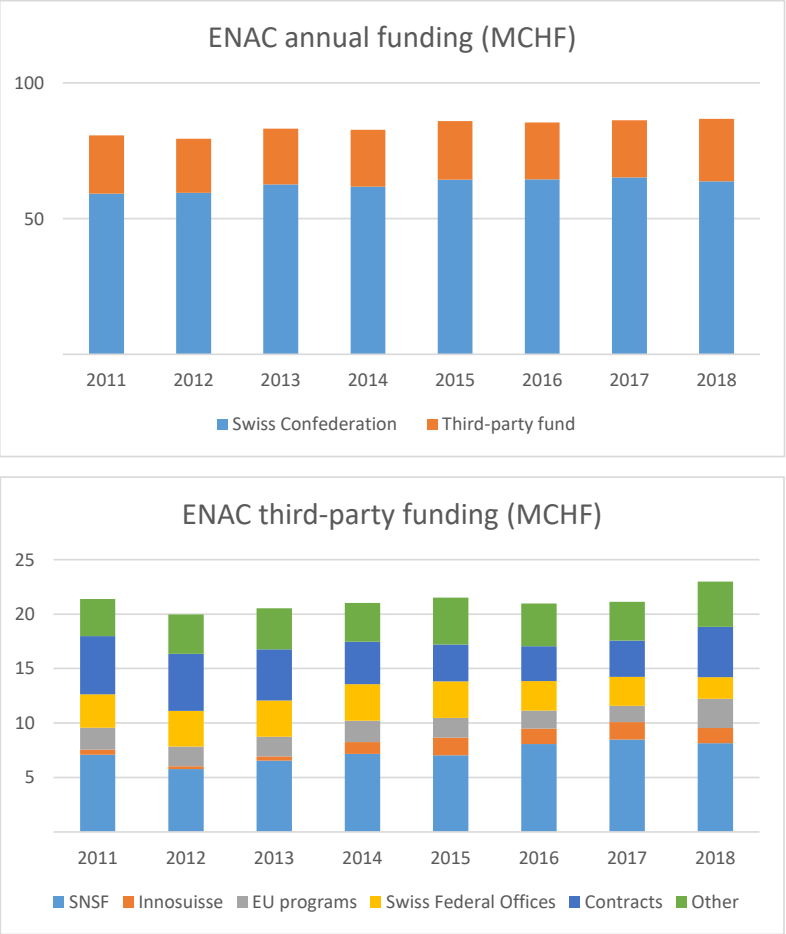


Figure 2.3. (Upper) This chart displays sources of expenditures. The Swiss Confederation supports the main part of ENAC expenditures. (Lower) This chart displays all third-party sources. The main funding is from the Swiss National Science Foundation (SNSF). Innosuisse is a Swiss government funder that supports technology transfer and innovation projects. EU programs include Horizon 2020 projects. Swiss federal offices are involved in different fields like energy, transport, environments and more. Finally, the “contract” category includes private and public projects.

The Institutes of Civil Engineering and Environmental Engineering attract a similar level of third party funds. Architecture is slightly below the other Institutes due to a low level of research projects in its domain (Figure 2.4).

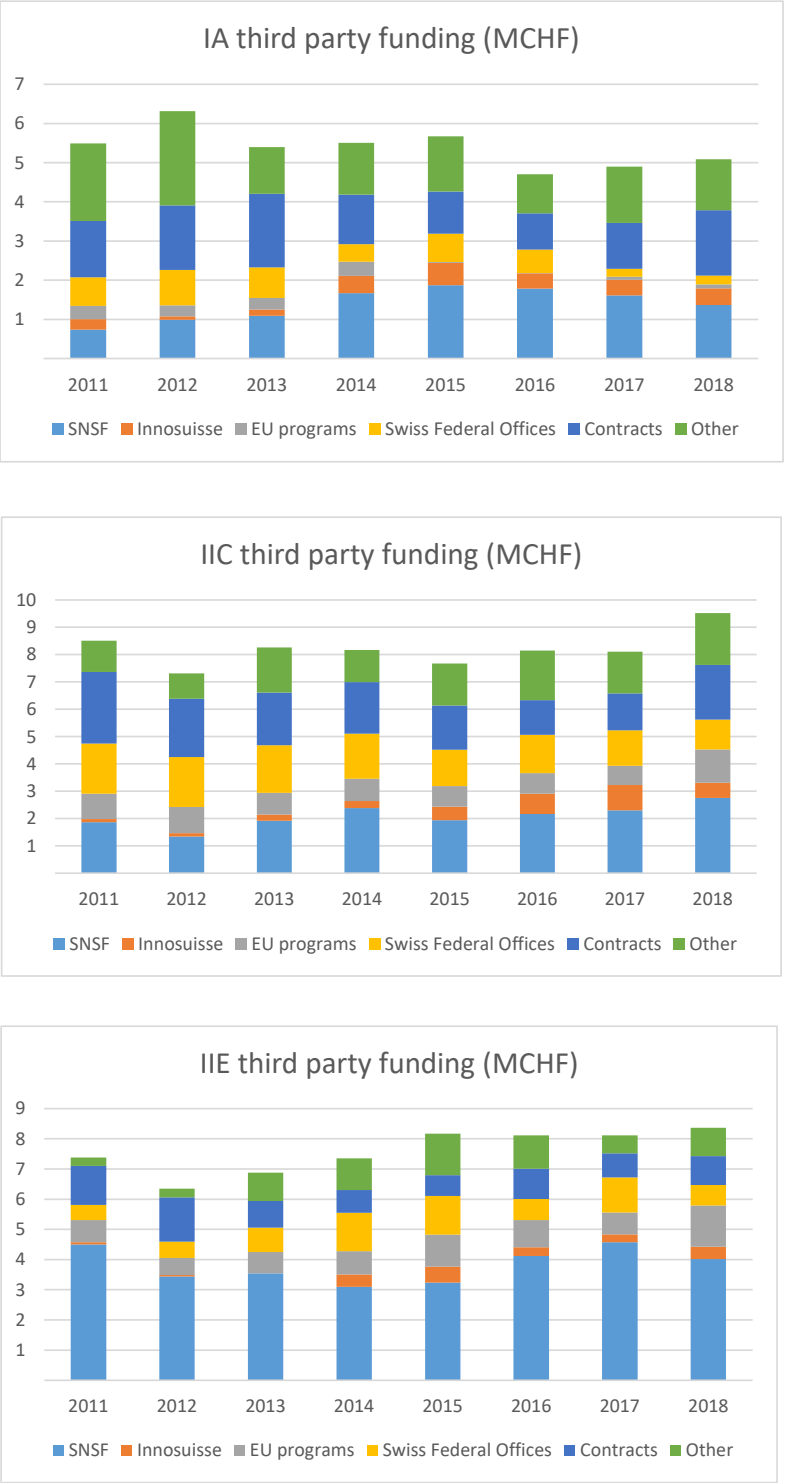


Figure 2.4. Institute third-party funding by source (2011-2018).

2.5 Interdisciplinary Collaboration

2.5.1 Collaboration within ENAC

At ENAC, several scientific communities come together under one roof: environmental engineers, civil engineers, architects, and social scientists. Combining disciplinary depth and interdisciplinary breadth, our teaching and research activities contribute to the common goal of finding solutions for a sustainable future by engaging together about the quality of our environment.

Due to ENAC's academic and intellectual diversity, it engenders collaborations that frequently have a distinctly interdisciplinary flavor. ENAC has a long tradition of interdisciplinarity, ongoing since its inception in 2002. The different elements of the faculty's collaborations are found in different areas.

- **Research** – ENAC leads or has strong involvement in competence centers such as the Smart Living Lab (SLL), the Transportation Center (TRACE) and the Habitat Research Center (HRC).
- **ENAC Research Days** – During the ENAC Research Days, researchers from all three Institutes come together to share new insights, get inspired by interesting speakers and engage in fruitful discussions across the disciplines. This event was relaunched in 2015 with a new format. Carefully selected invited speakers present topics with a cross-disciplinary perspective. A research exposition showcases highlights from across ENAC in an interactive setting. New potential collaborations originate from 'serendipity tables' where participants were shuffled into small interdisciplinary groups to think up research projects at their intersection between their areas of expertise. As a follow-up to each Research Day, the faculty organizes 'Visit My Lab' visits to further facilitate intra-ENAC collaborations. A short movie of the 2018 Research Day is available.¹
- **ENAC Exploratory Grants** – To stimulate the development of new interdisciplinary research, a semi-annual call for propositions for ENAC Exploratory Grants was launched for the first time in the context of the Research Day 2016. With this ENAC internal funding, three new interdisciplinary collaborations (resulting from the 'serendipity tables') were supported. A second call was organized in the context of the Research Day 2018, resulting in financial support for seven interdisciplinary projects involving more than 20 junior and senior researchers from ENAC from the fields of architecture, civil engineering and environmental engineering.
- **Education** – Collaboration in education is realized in the cross-sectional teaching program Design Together and the interdisciplinary Minors. Project-based education is a characteristic of ENAC. Often the projects put forward in the Design Together courses either emerge from research or lead into a research project. A flagship project, the Swiss Living Challenge, won the 2017 US Solar Decathlon competition. ENAC supports initiatives embedding interdisciplinary student projects into the curriculum, for instance with the newly created Student Kreativität and Innovation Lab (SKIL).
- **Affinity Map** – The Affinity Map² is a visual representation of existing connections within ENAC. For example, collaborations between the different ENAC laboratories are visualized in the Affinity Map, which also uncovers synergies in terms of joint teaching activities, co-supervision responsibilities and co-authored publications. The map can also be used as a diagnostic to identify missing linkages that should be encouraged.

Different, high-profile centers promoting collaboration both within and externally to EPFL follow.

¹ <https://www.epfl.ch/schools/enac/about/events/enac-research-day-2018/>

² <https://affinitymap.epfl.ch/>

2.5.1.1 Smart Living Lab (SLL, EPFL Fribourg)

The Smart Living Lab (SLL) is a research and development center dedicated to the built environment of the future. It was created in 2014 as a joint initiative of EPFL with the Canton of Fribourg, and is now part of the network of extended campuses developed by EPFL in Western Switzerland (Geneva, Sion, Neuchâtel, Fribourg). ENAC played an instrumental role in the creation of the Fribourg site. Four chairs and a research group were created, all part of ENAC. Located at the blueFACTORY site in central Fribourg, the Smart Living Lab plays a key role in the Switzerland Innovation Park Network West EPFL.

Context and Infrastructure – The Smart Living Lab was created in Fribourg with two academic partners: the University of Fribourg (UniFR) and the School of Engineering and Architecture of Fribourg (HEIA-FR), which is part of the universities of applied sciences in Western Switzerland (HES-SO). By the end of 2018, the Smart Living Lab had 11 research groups: 5 from EPFL, 3 from HEIA-FR and 3 from UniFR, which make for a unique inter-institutional structure.

EPFL Fribourg is located at the blueFACTORY, a historical industrial site in the city of Fribourg converted into an innovation district. As noted above, the blueFACTORY is affiliated with the Switzerland Innovation Park (SIP) Network West EPFL. Since 2015, the research groups are hosted in a temporary building at blueFACTORY. A new building dedicated to the Smart Living Lab is being developed. It is currently in its design phase and planned to be completed in 2022. This building aims to meet the ambitious environmental performance targets set by the Swiss Energy Strategy for 2050. The building itself will act as a full-scale experimental site for the 130 research staff members working in it. Its adaptable design will accommodate various interchangeable components and prototypes that can be tested in real-life situations. Not only the building, but also the current design process is

itself an innovative departure from current norms, and is the result of a research program conducted at the Smart Living Lab. At the heart of the design process are professional teams including architecture and engineering offices that interact with the scientific community of the Smart Living Lab to experiment with methods and tools proposed to enable low-carbon design.

The Smart Living Lab has already proven itself as a creative incubator as the birthplace of the NeighborHub, the Swiss solar house that won the US Solar Decathlon 2017 competition (section 4.4.2). Following the competition, the NeighborHub returned to the blueFACTORY and is now used as a research prototype for the purposes of energy management and user comfort. It simultaneously serves the local community, acting as a multifunctional gathering place and an information center on human-centered sustainable design and living.

Other experimental facilities of the Smart Living Lab include the atelier popup, a 900-m² workshop equipped with machines and tools for students to conduct hands-on projects and build large prototypes. Another research facility, the 1 to 1 Box, comprises two similar rooms for testing different comfort conditions and levels of automation. These facilities are additionally used for teaching projects led by ENAC professors based in Lausanne.

Academic Framework – The Smart Living Lab is an interdisciplinary research platform addressing the questions of human well-being at the same level as environmental and energy issues. It explores the opportunities of the digital transformation and offers facilities for full-scale experimentation. Its managerial organization is described in Figure 2.5.

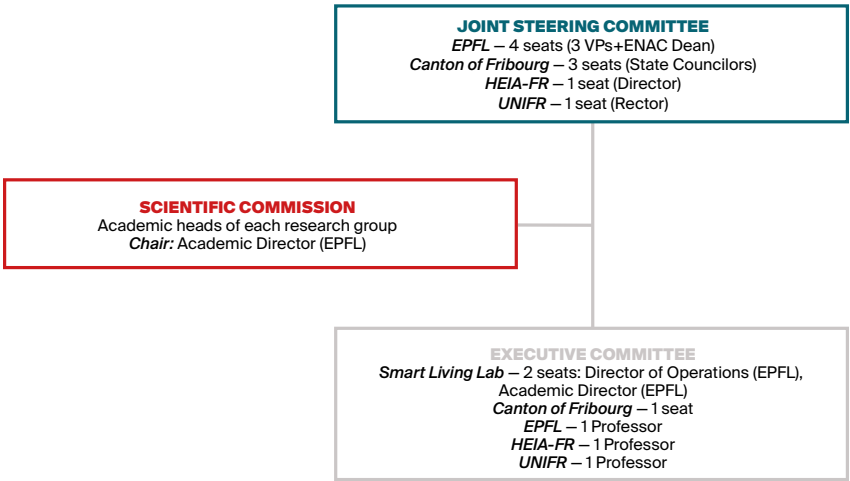


Figure 2.5. Managerial organogram of the Smart Living Lab.

The four main research domains investigated at the Smart Living Lab are:

- Well-being and behaviors
- Energy systems
- Interactions and design processes
- Construction technologies

The four ENAC laboratories in the SLL are:

- Structural Xploration Lab (SXL), Prof. Corentin Fivet (IA)
- Laboratory of Construction and Architecture (FAR), Prof. Paolo Tombesi (IA)
- Thermal Engineering for Built Environment Laboratory (TEBEL), Prof. Dolaana Khovalyg (IIC)
- Human-Oriented Built Environment Lab (HOBEL), Prof. Dusan Licina (IIC)

The fifth EPFL group at the Smart Living Lab is the Building2050 Group. From 2014 to 2018, the mission of the Building2050 Group was to carry out an ambitious research program in collaboration with the other groups able to define the objectives for the future building of the Smart Living Lab. As indicated above, this building is both a laboratory in itself as well as a demonstration building to address sustainability goals for 2050. The outcomes of this research program include numerous scientific publications, as well as a comprehensive book publication. The Building 2050 group has, since early 2019, a new mission of research support for the various laboratories and groups affiliated with the Smart Living Lab, notably in the monitoring of its infrastructure and in federating collaborations within and beyond the Lab.

The Smart Living Lab fosters interdisciplinary collaboration by funding joint research projects involving multiple research groups. The associated (non-EPFL) research groups of HEIA-FR and UniFR in the Smart Living Lab cover disciplines encompassing building technology, energy management, urban planning, building materials, management of technology and innovation, construction law and human-building interfaces drawing on a combination of IT, psychology and sociology.

The SLL also supports international educational exchanges, the most prominent example being the Swiss-Korean Academic Exchange Program focusing on sustainable and comfortable built working environments in the framework of summer and winter exchange schools.



2.5.1.2 Alpine and Polar Environment Research Center (ALPOLE, EPFL Valais, Sion)

The [ALPOLE](#) research center is part of ENAC's Institute of Environmental Engineering (IIE). It will, in the coming years, substantially expand the Institute's research and teaching programs. Several research groups from cognate scientific

disciplines within IIE will be co-located with ALPOLE at Sion, creating a large (up to 150 people) and synergistic research effort on climate-driven environmental changes and adaptations (section 5.4.3.6).

2.5.2 ENAC Extended Community

ENAC has strong links with research Institutes of the ETH domain. Four ENAC professors hold joint appointments with the Swiss Federal Institute of Aquatic Science and Technology (Eawag): Prof. Urs von Gunten (full professor, Laboratory for Water Quality and Treatment), Prof. Janet Hering (full professor and Eawag Director, Prof. Hering Group in Environmental Chemistry), Prof. Kristin Schirmer (adjunct professor, Laboratory of Environmental Toxicology), and Prof. Alfred Johny Wüest (full professor, Physics of Aquatic Systems Laboratory).

With the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), ENAC shares three professorships: Prof. Alexandre Buttler (adjunct professor, Ecological Systems Laboratory), Prof. Michael Lehning (full professor, Laboratory of Cryospheric Sciences), and Prof. Konrad Steffen (full professor and WSL Director, Prof. Steffen Group in Cryosphere Sciences).

Prof. Christian Ludwig (adjunct professor) holds the EPFL-PSI Joint Professorship on Solid Waste Treatment, shared with the Paul Scherrer Institute (PSI).

In addition, ENAC hosts the following units:

- The Swiss Romande (French-speaking part of Switzerland) branch of the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL Lausanne), directed by Prof. Alexandre Buttler
- The Soil and Sediment Ecotoxicology Group of the Eawag-EPFL Ecotox Center (Swiss competence center for applied, practice-oriented ecotoxicology), headed by Dr. Benoît Ferrari
- The Chair of Law (Chaire de droit – CDT) of the University of Fribourg at EPFL, under the responsibility of Profs. Isabelle Romy and Jacques Dubey

Other joint ENAC professorships are:

- Prof. Jeffrey Huang (head of the Media and Design Laboratory, IA) with the School of Computer and Communication Sciences (IC)
- Prof. Jean-François Molinari (head of the Computational Solid Mechanics Laboratory, IIC) holds a courtesy appointment at the Institute of Materials of the School of Engineering (STI).
- Prof. Anders Meibom (head of the Laboratory for Biological Geochemistry, IIE), is full professor ad personam at the Institute of Earth Sciences at the neighboring University of Lausanne.

2.5.3 Collaboration with other EPFL Laboratories and Beyond

ENAC laboratories are involved in various EPFL-wide Centers. Administratively, EPFL Centers are directly attached to one of the three academic Vice-Presidencies for Education, Innovation and Research. Six of these interdisciplinary centers are directed or co-directed by ENAC professors:

- Transportation Center (TRACE), Director: Prof. Michel Bierlaire
- Habitat Research Center (HRC), Director: Prof. Paola Viganò
- Limnology Center (LIMNC), Director: Prof. Alfred Wüest
- Energy Center (CEN), Directorate member: Prof. Claudia Binder
- Cooperation and Development Center (CODEV), Director: Prof. Jean-Claude Bolay
- Swiss Polar Institute (SPI), Director: Prof. Konrad Steffen

Note that the SPI, located at EPFL, is a Swiss-wide endeavor promoting polar research. ENAC laboratories are furthermore involved in other EPFL-wide centers such as the [EPFL+ECAL lab](#), the Space Engineering Center ([eSpace](#)), and the Swiss Space Center ([CTS](#)). Examples of centers with major ENAC involvement are discussed below.

2.5.3.1 Transportation Center (TRACE)

The center [TRACE](#) was created in ENAC and is dedicated to transportation topics. Its broad research remit casts its net across EPFL, thereby serving as an excellent example of interdisciplinary collaboration within EPFL (see section 6.2.2 for a detailed description).

2.5.3.2 Habitat Research Center (HRC)

The [Habitat Research Center](#) was created in June 2016. It is an inter-pluri-trans-disciplinary research platform, aiming to explore urban phenomena and to produce visions, strategies and projects on this primary and crucial topic. Bridging research, teaching and design, the HRC brings together all relevant expertise within ENAC. The center's interests span ecological, technological and social aspects of

urbanism, pursued with a future-oriented and interdisciplinary design approach as a core research tool.

The HRC brings together numerous EPFL research groups: ALICE, CEAT, ECOS, HERUS, IMAC, LAB-U, LASIG, LAST, LASUR, LIPID, LCC, MCS, SBER, TSAM (all from ENAC), and outside ENAC; DHLAB (CDH); DLAB (IC); LIDIAP (STI).

The HRC has formulated four Interdisciplinary Research Clusters to guide its agenda in the coming years, and to coalesce and enhance research in urban systems:

- *Healthy Habitats – Visionary and integrated solutions to improve wellbeing and health in cities* (launched November 2018) – The preservation and pursuit of quality of life in cities represents a fundamental challenge for the future. Healthy Habitats aims to develop visionary and innovative solutions to improve well-being in cities based on an integrated, interdisciplinary research agenda.
- *Digital Habitats – Exploring how data technology changes space and life* (launched December 2018) – Digital Habitats uses new technological and scientific knowledge to provide policies, designs and services that achieve a better quality of life. By focusing on the future of metropolitan living and urban-rural contexts, this cluster will find global and local solutions that match the complexity of world societies.
- *Landscape Habitats – Designing integrated, regional ecological networks* (Spring 2019 launch) – Landscape Habitats addresses the elemental habitats of soil, water and air – first for their own sake, then as the basis for regional conservation efforts, and finally as material and energetic cycles reinforcing rural and urban territories.
- *Productive Habitats – Understanding the new paradigms of labor* (Spring 2019 launch) – In the relationship between production activities and territory, labor has profoundly changed in recent decades. In this period of economic transition, Productive Habitats will develop hypotheses to understand how the new paradigms of labor will transform cities and territories.

HRC's activity (funded since September 2017) has been broad and manifold; two Clusters have already produced a set of research activities to promote cooperation and trigger innovation within EPFL laboratories. The launch of a Seed Money Call for one-year interdisciplinary projects, supported by the Digital Habitats Cluster in collaboration with the Europe Time Machine group, has produced new knowledge on 4D data-modeling applied to the urban context. The promotion of an international research project on Urban Walking Continuities (SNSF and H2020 proposals), launched by the Healthy Habitats Cluster, has shown the capacity to bring together urbanism and medicine to produce novel interpreta-

tions of urban space. In 2018 the Center has been selected as one of the seven international interdisciplinary teams to work on the International Project: [Prospective Visions for the Greater Geneva](#). A dense program of initiatives (April-June 2019) is foreseen to launch the third Cluster: Landscape Habitats.

HRC has organized several international events as seminars and talks on both theoretical and methodological interdisciplinary issues and is engaged in interdisciplinary teaching activities as the Minor Urbanism in Transition.



2.5.3.3 Energy Center (CEN)

Mission – The mission of the [Energy Center](#) is to catalyze energy research led by EPFL laboratories, notably in collaboration with industrial and institutional partners, and to enhance EPFL's impact as a world leading research and education institution contributing to the transition towards a sustainable energy future.

History and Current Role – CEN was founded in 2006. It is an EPFL-wide center embracing disciplinary perspectives on regarding energy at EPFL and bringing together research, industry and administration. Today, the transition to sustainable energy systems as one of the most daunting and fundamental challenges of modern society is shaping the current role of CEN. Climate change, sustainability as well as security of energy and food supply call for unprecedented development and innovation in energy sciences, technologies, systems and coupled policy and societal measures. A holistic perspective on the energy transition shapes the EPFL Energy Center's role to catalyze laboratories' research and teaching

within all relevant EPFL disciplines in the broad area of energy integrating collaboration with institutional and industry partners. In doing so, it facilitates the formulation of fundamental moon-shot challenges in alignment with, or aiming to help define, the broader EPFL strategy.

Organization – The Center is composed of an executive director and a directorate board, which is composed of 5 persons from different faculties and experts in the energy field. Over 72 labs perform research in the energy area, 28.7% out of which are from ENAC. The Center works in collaboration with the EPFL Vice Presidents for Research and Education in order to guarantee alignment with the strategic directions defined by EPFL.

Activities – CEN organizes clusters and supports the research of EPFL faculties and laboratories active in the areas of basic science, materials for highly-efficient devices, complex energy systems, big energy data, energy markets, policies and

society impact/implications. Additionally, the Energy Center coordinates EPFL laboratories interested in realizing large-scale infrastructure targeting the study of future energy systems as well as demonstrating the feasibility of realistic-scale energy conversion devices. Finally, the Center also coordinates education programs in energy for the Bachelor, Master and PhD levels. The key activities in each of these pillars is presented in Figure 2.6.

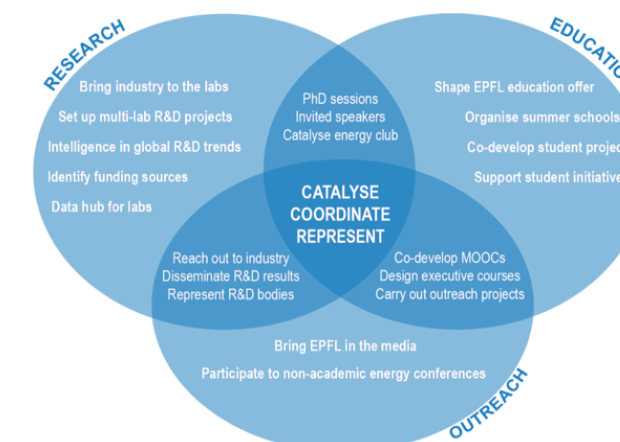


Figure 2.6. Key activities of the Energy Center.

Major achievements of CEN include:

- Coordination of the EPFL energy community so that, according to the Shanghai University Ranking in the field of Energy Science and Engineering, EPFL ranked second worldwide in 2018.
- Development of the new EPFL Master in Energy Science and Technology. The EPFL Master in Energy Science and Technology provides a world-class educational environment to train students in charge of developing future technologies in the field of energy engineering.
- Provision of fundamental inputs for the definition of the Swiss Master Plan for Energy Research as well as to the EU SetPlan.

2.5.3.4 Limnology Center (LIMNC)

The sustainable use and conservation of natural water resources is among the most important challenges for the well-being of the future nine billion earth citizens. The [Limnology Center's](#) mission is to provide socially-relevant contributions in water research, both nationally and internationally, while facing future challenges due to increasing anthropogenic pressure and global change. LIMNC aims at becoming a competence center in freshwater systems science and technology, where scientists from different domains work together in an integrated and interdisciplinary approach. The LIMNC has initiated or participated in different (international) projects involving large teams of researchers, including projects that were underway when the center was formed in 2013, as described below.

Project elemo (field campaign in 2011) – This highly-publi-

cized project was centered around an intense deep dive campaign in Lake Geneva using the Russian MIR submarines (Figure 2.7). Numerous international and Swiss scientists participated in this interdisciplinary project that followed the concept “from source to sink,” i.e., the fate of water entering the lake, with findings reported in numerous articles, PhD theses and the 2016 book *Dans les abysses du Léman*.

Léman-Baikal Project (2013-2015) – This project involved multiple teams with a common theme of aerial investigations of the water quality of Lakes Geneva and Baikal from the air, using microlight aircraft and a prototype hyperspectral camera. Besides the scientific contributions, the project was instrumental in initiating the creation of a successful start-up focusing on novel hyperspectral camera technology and associated data treatment, [Gamaya](#).



Figure 2.7. MIR submarines (project elemo) being prepared for missions in Lake Geneva in 2011 (©Alain Herzog).

Lake Onego – Life Under Ice (field campaigns 2015-2017) – LIMNC led a large multidisciplinary [project](#) on Lake Onego, Europe's largest freshwater lake. Over 40 scientists from Russia, Switzerland, France, Germany and Sweden representing diverse limnological fields including physics, chemistry, biology, sedimentology and remote sensing participated (Figure

2.8). The research program investigated life under ice and the relevant physical, chemical and biological processes during seven field campaigns. Ecosystem functioning as affected by under-ice convection and the impacts of the ice-covered period were investigated, along with carbon emissions at ice break-up.



Figure 2.8. Scientists working from the ice on Lake Onego in Petrozavodsk Bay – March 2016.



Figure 2.9. LéXPLORE platform anchored on Lake Geneva near Pully – February 2019.

LéXPLORE Platform – Since 2014, LIMNC initiated and led the installation of a physical pontoon for in situ limnological research on Lake Geneva, in conjunction with several partners (University of Geneva, University of Lausanne, Eawag and INRA at Thonon-Les-Bain). The project recently reached its

first major milestone with deployment of the instrumented platform in February 2019 (Figure 2.9). This unique infrastructure will support experimental research using high-frequency, state-of-the-art instrumentation.

2.5.3.5 Cooperation and Development Center (CODEV)

The Cooperation and Development Center ([CODEV](#)) promotes innovative technologies to support social, environmental and economic development in the Global South. It supports collaborations between EPFL laboratories and stakeholders in the Global South through Seed grants. These impact-oriented research projects are valuable ins-

truments to enable research partners in the Global South to access innovative technologies and methodologies through knowledge transfer from EPFL. Between 2011 and 2018, ENAC researchers were granted 26 research projects through the EPFL Seed Funding Program managed by CODEV (see section 6.5.7 for more information).

2.5.3.6 Swiss Polar Institute (SPI)

The Swiss Polar Institute ([SPI](#)) was founded in 2016 to offer new opportunities and funding to researchers based in Switzerland who work in the polar regions. It is currently funded by its founding members: EPFL, WSL, ETHZ, University of Berne, and the (private foundation) Editions Paulsen. SPI is headquartered within ENAC.

In 2018, SPI launched dedicated funding opportunities to complement existing offers and to fill gaps linked to the specific needs of science in Polar regions. The Polar Access Fund offers young researchers funding to complement their research with a field trip to a Polar region (Figure 2.10). SPI Exploratory Grants offer seed funding to start new collaborations and fund logistics related to research projects in those regions. Additionally, students can benefit from SPI funding to participate in training, and in international field/maritime

schools (Figure 2.11).

Organizing and implementing scientific expeditions forms a core part of SPI's mission. In 2016-2017, SPI organized the Antarctic Circumnavigation Expedition ([ACE](#)) which took 22 international scientific projects on a three-month expedition to collect samples and data (oceanographic, terrestrial, atmospheric and cryospheric) from the Southern Ocean, sub-Antarctic islands and the Antarctic continent. [GLACE](#), an expedition around Greenland is planned for summer 2019. It involves 15 projects that have been competitively selected to take part, including participation from ENAC.

SPI and its close association with ENAC will be enhanced by the parallel development of ALPOLE (section 5.4.3.6), particularly since SPI will be co-located with ALPOLE at Sion.



Figure 2.10. Different projects funded by the SPI Polar Access Fund (2018).



Figure 2.11. Health and safety course at Sion in 2018 with GRIMM (Groupe d'Intervention Médicale en Montagne).

2.5.3.7 Collaborations Outside EPFL

At the national level, large-scale competitive projects are organized into [NCCRs](#) (National Centers of Competence in Research). ENAC researchers have been involved in a variety of cross-institutional collaborative projects at the national scale in recent years, including NCCRs, e.g., the [NCCR Robotics](#) (EPFL, ETH Zürich, University of Zürich, Istituto Dalle Molle di Studi sull'Intelligenza Artificiale Lugano, University of Bern) and the [NCCR Digital Fabrication](#) (ETH Zürich, EPFL, Hochschule für Technik Rapperswil, Lucerne University of Applied Sciences and Arts, Bern University of Applied Sciences, Empa). ENAC laboratories also participate in different National Research Programs ([NRPs](#)), which involve a series of coherent projects around a common theme, such as the [NRP 70: Energy Turnaround](#), which focuses on the scientific and technological aspects of the change in energy strategy and the corresponding changeover to a new energy system for Switzerland and the [NRP 73: Sustainable Economy](#) aiming at generating scientific knowledge about a sustainable economy.

ENAC faculty members received several [Sinergia](#) grants from the Swiss National Science Foundation (SNSF). These grants support interdisciplinary collaborative research on different topics, such as the now finished [PostCarWorld](#) in collaboration with ETH Zürich and Università della Svizzera italiana (USI). Recent, on-going projects include “Elucidating the success of microbial biofilms and their implications for habitability and ecosystem evolution in glacial floodplain streams” (EPFL, University of Lausanne, ETH Zürich, University of Luxembourg) and “African contributions to global health: Circulating knowledge and innovations” (EPFL, University of Basel).

Switzerland is actively planning its future energy strategy. In this context, it supports Swiss Competence Centers for Energy Research ([SCCERs](#)), which are financed by the Swiss Innovation Agency (Innosuisse). ENAC researchers participate in the SCCER [Future Energy Efficient Buildings and Districts](#), which will develop solutions for a factor three reduction in the environmental footprint of Swiss building stock by 2035 through efficient, intelligent and interlinked buildings. The [SCCER Supply of Electricity](#) carries out innovative and sustainable research on the supply of electricity from hydropower and geogeneity in order to meet the challenges of the [Energy Strategy 2050](#), which foresees a major increase in the use of renewables and the closure of five existing Swiss nuclear power stations.

At the international level, ENAC researchers are collaborating with many universities and research institutions worldwide. For instance, in 2017 ENAC researchers reported more than 300 ongoing collaborations in involving more than 200 different universities and research institutions from 46 different countries. These collaborations are productive: An analysis of documents indexed in Web of Science reveals that 80% of the top-20 institutions co-publishing with ENAC researchers in the period 2008-2017 are located outside of Switzerland, namely in the US and Europe (Source: InCites, extracted on 20 December 2018). For instance, faculty members of ENAC are active in the [Future Cities Laboratory](#), a research program established by ETH Zürich and Singapore's National Research Foundation that aims to develop new knowledge, technologies, and approaches for a sustainable urban future with an Asian perspective.

3. Faculty

3.1 Overview

EPFL follows the North American model of Tenure-Track Assistant Professors (PATT, Professeur/e Assistant/e Tenure-Track), and tenured Associate (PA, Professeur/e Associé/e) and Full Professors (PO, Professeur/e Ordinaire). The tenure evaluation is thus coupled with promotion to Associate Professor. At EPFL, all PATTs, PAs and POs lead an independent laboratory (research group), and are responsible for all aspects of the group, including hiring, research agenda and external funding.

A research and teaching career as a scientist is also possible at EPFL. The academic titles in this case are Research and Teaching Associate, Senior Scientist (MER, Maître d'enseignement et de recherche) and Adjunct Professor (PTIT, Professeur/e titulaire, also referred to as Titular Professor). A major difference with the abovementioned professor roles is

that the scientist path typically does not involve leadership of a laboratory. Rather, these positions are usually placed within a laboratory (where they may lead a subgroup). Scientists have PI (Principal Investigator) status and can thus seek external research funding. MERs and PTITs have the authority to supervise PhD students as primary or sole advisors.

Finally, ENAC hosts a number of non Tenure-Track Assistant Professors. These professors are based on individual competitive SNSF grants awarded to the professors. Note that, at EPFL the title of non Tenure-Track Assistant Professor does not exist; it is used here for convenience to denote the approximate rank of the appointee. At EPFL the correct title is SNSF Eccellenza Professor.

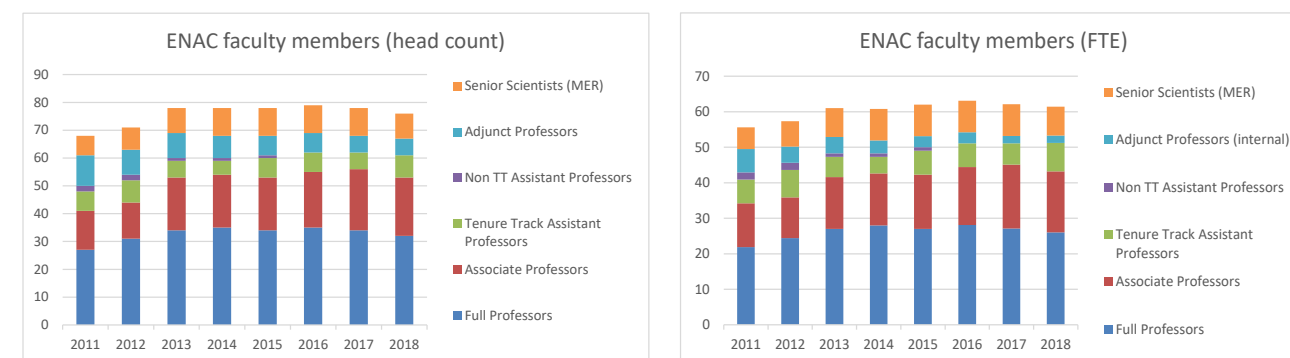


Figure 3.1. Evolution of ENAC faculty members since 2011. (Left) Head count, including joint professorships with other Institutes of ETH domain. (Right) Full Time Equivalents (FTE), considering into account only activity rates at EPFL

Figure 3.1 shows the total and distribution of professors and senior scientists in ENAC, by headcount and by FTE. There has been little change in the total numbers of professors during the past five years. This is mainly due to a flat budget during this period. As a federally-funded institution, all permanent and many non-permanent positions must be within the government funding line. Externally funded professorships increase the headcount only during the period

of external funding, since afterwards they revert to the government funding line. It is evident also that the distribution of different professorial and scientific ranks has changed little since 2013. This situation could change in the coming years due to retirements (mandatory at 65 years in Switzerland). In particular, the proportion of PATTs will likely increase given the EPFL preference to hire at this level.

3.2 Recruitment and Promotions

3.2.1 Faculty Recruitment Strategy

Professorships are located within Institutes. Affiliations in more than one Institute are possible, although in practice rare in ENAC. Faculty slots are derived from, and are in support of, Institute strategic plans. Because of the close relationship between Institutes and Sections, the educational vision of each Section is naturally integrated into the definition of new professorships.

Departures or retirements of faculty result in laboratory closure, i.e., there is no automatic continuation of any laboratory. Instead, all new faculty slots are based on the vision and strategy of the Institute, as formulated in its strategic plan. This policy provides the impetus for a forward-thinking reimagining of the Institute's research profile with every new hire. As discussed elsewhere (section 3.2.5), ENAC will experience turnover of approximately a third of its faculty up to 2025, giving ample opportunity for each Institute to pursue new research directions. Note that faculty slots do not automatically revert to Institutes upon closure of a laboratory, although usually this is the case.

Attracting top-notch faculty members is a priority for ENAC. Since the last evaluation in 2011, the School has been successful in hiring highly reputable scientists from the best international institutions. The emphasis has been primarily on

the recruitment of promising young scientists and on female scientists, with the support of the ENAC Gender Equality Working Group (ENGW). Efforts are also made in ensuring a balanced faculty distribution across the ranks and disciplines.

ENAC's professoriate includes research-intensive scientists, engineers and architects who engage in basic and applied research. It also includes practice-oriented professors, mainly in Architecture. Typically, these professors have fractional appointments at EPFL in addition to their independent professional practices (e.g., 50% EPFL and 50% practice). This group of professors is essential to ENAC's mission to educate students to professional readiness, particularly in Architecture. However, their research profiles are not adapted to those typically encountered in a research-intensive institute of technology. For that reason, ENAC proposes a new title, Professor of Practice (section 3.2.6), to distinguish this important group. Along with the new title, a new evaluation and promotion pathway that identifies excellence in this genre of professor would be elucidated. It is anticipated that other programs in ENAC (and EPFL) could find it beneficial to include Professors of Practice in their academic profiles.

3.2.2 Recruitment Process

Recruitments are based on the vision of each institute, and are further evaluated by the ENAC Senior Management. All professor positions at EPFL are presented to the EPFL Management annually during the Dialogue meeting (early summer), during which each professorship is analyzed in detail in the light of the ENAC strategy.

After approval at the Dialogue, a Search Committee is formed, chaired by the relevant Institute Director. It consists of the ENAC Dean, several internal experts, a faculty member of the ETH Domain, an external international academic expert, a representative from industry, and an undergraduate student. Gender-balanced committees are sought, in line with EPFL policy. The committee has the task to proactively seek out and encourage outstanding applicants, with a priority placed on potential female candidates.

The Search Committee analyses all files, and selects a short list of candidates. All candidates are welcomed with a structured visiting program, which includes a research seminar

and a closed-door interview. The final selection of the Search Committee – one candidate or a ranked list – is validated by the Dean and the committee Chair. The Dean then formulates a dossier that is submitted to EPFL management to initiate the second step in the hiring process. This step entails a second visit with the EPFL Management, as well as additional interactions with ENAC. The final decision on all appointments is taken by the EPFL President. Successful candidates receive a detailed offer. The final formal step is that EPFL nominates the candidate to the ETH Board, which must approve each professorship. The entire process usually takes one year.

Professors' salaries are set by the ETH Domain bylaws, and depend on the academic rank. The startup funds vary depending on seniority but also on specific infrastructure needs and costs, and are negotiated with each appointee.

3.2.3 Promotion Process

ENAC has a promotion committee (CEA ENAC, Commission d'évaluation académique), composed of two full professors from each of the three Institutes, i.e., six members, including the Chair. The committee deals with all academic promotions ranging from professors' promotion to academic titles for scientists. The promotion processes are described in the EPFL bylaws.¹

For the tenure process, ENAC's procedure is:

- **Annual Report and Faculty Meeting** – Each year, PATTs submit a report based on the criteria for promotion. A faculty meeting (restricted to tenured professors) evaluates each case, which is presented by the relevant Institute Director. Oral and written feedback is given in a (later) meeting with the Dean, Institute Director and PATT.
- **Midterm Review** – This occurs midway through the six-year tenure clock, i.e., after three years. It is intended as a constructive evaluation. The PATT submits a file following the format of the final tenure dossier. An external expert is invited to visit his/her laboratory, and meet with his/her team. The PATT makes an oral presentation of his/her dossier to the expert, the Dean, the Institute Director, the CEA ENAC, as is required for the formal tenure evaluation. Following the midterm review, the PATT receives oral and written feedback from the Dean and the Institute Director.
- **Tenure Process** – The candidate submits his/her dossier by the end of the sixth year after appointment. The file is submitted to the Dean, who delegates the CEA ENAC to carry out an in-depth evaluation. An important part of the process is a research presentation to the PATT's Institute (organized by the CEA ENAC), which is followed by an up/down vote by the tenured professors. The CEA ENAC seeks external (from international experts) and internal letters, interviews the candidate, makes a detailed evaluation of the dossier, and gives its final assessment to the Dean (including the results of Institute vote, and the CEA ENAC vote). The Dean then evaluates the dossier and the CEA ENAC report. The Dean's evaluation, the CEA ENAC report and the dossier are then submitted to the EPFL President. The entire package is forwarded to the CEA EPFL, which additionally carries out its own analysis (including external letters and interview of the candidate). The CEA EPFL submits its report (and vote) to the President, who makes the final tenure decision.
- **Time Taken** – The entire tenure evaluation process takes up to one year. Unsuccessful PATTs typically leave EPFL about a year after their tenure decision.

Since 2011, the promotions to tenure for ENAC PATTs were successful for five professors, and unsuccessful for two. Promotion from Associate to Full Professor follows the same procedure as for PATTs. Since the last Audit, promotion to PO was granted to four professors, and denied to two.

For the scientist track:

- Dossiers are considered by the CEA ENAC, which seeks external and internal letters, and interviews the candidate.
- The CEA ENAC sends its report (including its vote) to the Dean.
- If the Dean supports the promotion, he/she prepares his/her own evaluation, which is sent to the Vice President for Research. The EPFL Senior Management determines if the promotion should be accepted.
- If the Dean does not support the promotion, the process stops and the Dean provides feedback to the applicant.

¹ https://polylex.epfl.ch/wp-content/uploads/2019/01/4.2.1_r_professeur_tenure_track_en.pdf

Scientist track promotions since 2011 are as follows:

- Five collaborators were successful in being appointed as Research and Teaching Associates
- Four collaborators were promoted to MER
- Four applications to MER were not supported by the CEA ENAC and Dean
- One application to MER was supported by the CEA ENAC and Dean but denied by the EPFL Senior Management
- No promotions to Titular Professor were successful (three applications were not supported by the CEA ENAC and Dean)

3.2.4 Hires and Promotions Since 2011

Hiring and promotion processes have academic quality at the international level as the main criterion. Professors appointed and promoted since 2011 are listed in Tables 3.1 and 3.2.

Table 3.1. Faculty appointments to ENAC since the end of 2011.

NAME	FIRST NAME	INSTITUTE	LAB ACRONYM	RANK	YEAR
LEHNING	Michael	IIE	CRYOS	PO	2011
SCHIRMER	Kristin	IIE	TOX	PTIT	2011
MEIBOM	Anders	IIE	LGB	PO	2012
STEFFEN	Konrad	IIE	UPSSC	PO	2012
TAKAHAMA	Satoshi	IIE	APRL	PATT	2012
WÜEST	Alfred Johny	IIE	APHYS	PO	2012
BAKKER	Marco	IA	MANSLAB	PA	2013
BLANC	Alexandre	IA	MANSLAB	PA	2013
BRAGHIERI	Nicola	IA	LAPIS	PA	2013
CACHE	Bernard	IA	CNPA	PA	2013
FRÖHLICH	Anja	IA	EAST-CO	PA	2013
FRÖHLICH	Martin	IA	EAST-CO	PA	2013
GEERS	Keers	IA	FORM	PA	2013
PERRAULT	Dominique	IA	SUB	PO	2013
VIGANO	Paola	IA	LAB-U	PO	2013
BATTIN	Tom	IIE	SBER	PO	2015
LECAMPION	Brice	IIC	GEL	PATT	2015
VAN GERREWEY	Christophe	IA	ACHT	PATT	2015
VIOLAY	Marie	IIC	LEMR	PATT	2015
BINDER	Claudia	IIE	HERUS	PO	2016
FIVET	Corentin	IA	SXL	PATT	2016
LIGNOS	Dimitrios	IIC	RESSLAB	PA	2016
TOMBESI	Paolo	IA	FAR	PO	2016
ALAH	Alexandre	IIC	VITA	PATT	2017
KHOVALYG	Dolaana	IIC	TEBEL	PATT	2018
LICINA	Dusan	IIC	HOBEL	PATT	2018
NENES	Athanasios	IIE	LAPI	PO	2018

Table 3.2: Promotions of ENAC professors and scientists since the end of 2011.

NAME	FIRST NAME	INSTITUTE	LAB ACRONYM	PROMOTION	YEAR
BIERLAIRE	Michel	IIC	TRANSP-OR	PA → PO	2012
MOLINARI	Jean-François	IIC	LSMS	PA → PO	2012
ANDERSEN	Marilyne	IA	LIPID	PA → PO	2013
HOLLIGER	Christof	IIE	LBE	PA → PO	2013
LALOU	Lyesse	IIC	LMS	PA → PO	2014
BERNE	Alexis	IIE	LTE	PATT → PA	2013
BERNIER-LATMANI	Rizlan	IIE	EML	PATT → PA	2013
KOHN	Tamar	IIE	LCE	PATT → PA	2014
GEROLIMINIS	Nikolaos	IIC	LUTS	PATT → PA	2015
BEYER	Katrin	IIC	EESD	PATT → PA	2017
REY	Emmanuel	IA	LAST	PATT → PA	2017
LALOU	Lyesse	IIC	LMS	PTIT → PA	2012
PATTARONI	Luca	IA	LASUR	Senior Scientist (MER)	2012
VASSILOPOULOS	Anastasios	IIC	CCLAB	Senior Scientist (MER)	2013
FERNANDEZ RUIZ	Miguel	IIC	IBETON	Senior Scientist (MER)	2014
CHENAL	Jérôme	IA	CEAT	Senior Scientist (MER)	2015

3.2.5 Future Faculty Retirements

ENAC retirements until 2028 are shown in Table 3.3. The total number of retirements is 27. Most of the listed professors are full time, and the majority of them will be replaced (not all since there are externally funded chairs within the Faculty that are expected to enter the funding allocation). This turnover is a significant proportion of the present professor FTE (Figure 3.1), and represents a major opportunity to reshape ENAC’s capabilities in order to meet future challenges, as identified by strategic priorities.

Table 3.3. Professor retirements until 2028, based on the mandatory Swiss retirement age of 65.

YEAR	NAME	LAB ACRONYM	INSTITUTE
2019	Jean-Claude BOLAY	LASUR	IA
	Alexandre BUTTLER	ECOS	IIE
2020	Bruno MARCHAND	LTH2	IA
	Ian SMITH	IMAC	IIC
2021	Roberto GARGIANI	LTH3	IA
	Harry GUGGER	LABA	IA
	Luca ORTELLI	LCC	IA
	Alfred Johny WUEST	APHYS	IIE
2022	Edgard GNANSOUNOU	GR-GN	IIC
	Jean-Louis SCARTEZZINI	LESO	IIC
2023	D. Andrew BARRY	ECOL	IIE
	Eugen BRUHWILER	MCS	IIC
	Bernard CACHE	CNPA	IA
	François GOLAY	LASIG	IIE
	Franz GRAF	TSAM	IA
	Bertrand MERMINOD	TOPO	IIE
	Aurelio MUTTONI	IBETON	IIC
	Laurent VULLIET	LMS	IIC
2024	Christof HOLLIGER	LBE	IIE
	Thomas KELLER	CCLAB	IIC
	Andrea RINALDO	ECHO	IIE
	Urs VON GUNTEN	LTQE	IIE
2025	Marco BAKKER	MANSLAB1	IA
	Paola VIGANO	LABU	IA
2026	Paolo TOMBESI	FAR	IA
2028	Lyesse LALOU	LMS	IIC
	Yves WEINAND	IBOIS	IIC

3.2.6 Proposal for *Professors of Practice*

ENAC's education programs are developed and delivered by professors, scientists and, to a lesser extent, external experts and practitioners. In addition, external placements for projects and practical work enrich the educational experience for students and expose them to professional activities.

As already mentioned above, in Architecture, but potentially in other programs, there is a close and direct connection to the profession that is mandatory for graduates. This connection is achieved by the appointment of Associate Professors who have strong practitioner profiles and are often part-time at EPFL while staying engaged in architectural firms. These professors have a different employment contract (renewable 4-year private law contract). Several professors in architecture have this profile. A major difference is that such professors do not have to satisfy expectations of research productivity as applied elsewhere in EPFL. Both within and externally to EPFL, this situation produces uncertainty due to the title of Associate Professor. Specifically, other Associate Professors (or Tenure-Track Assistant Professors) carry out research activities in addition to their teaching activities (doctoral students, fundraising, etc.), and undergo a rigorous evaluation for promotion. Because EPFL does not distinguish between these different demands and expectations, there is no formally-defined procedure to evaluate practitioner-professors. It would benefit EPFL's goal of excellence in its professoriate to articulate criteria and procedures for this category of pro-

fessors. Certainly, such professors will remain part of the fabric of ENAC's architectural education (and potentially other) programs.

ENAC suggests, therefore, that the title of *Professor of Practice in Architecture* (or other domains, as appropriate) be established to distinguish, both internally and externally, the different academic role of the holders of this title. As already suggested, it would be beneficial to have the opportunity to appoint such professors to civil or environmental engineering also. Such a title does not exist and would require a modification of the regulations at the ETH Domain level. Characteristics of Professors of Practice would be:

- Part-time, with employment outside of EPFL as an architect or engineer
- Reduced expectations for academic research
- Expectations of practice-oriented research
- Renewable contracts without tenure
- Promotion path that emphasizes teaching, professional engagement, innovation/research related to professional practice, and service

The benefits of this change would be a clear understanding and appreciation of the role of Professors of Practice, along with the ability to communicate the distinctive role played by such professors both within and outside of EPFL.

3.3 Junior Faculty Mentoring and Integration

EPFL, and ENAC, have in place several measures to guide PATTs through the sometimes difficult transition to group leader and PI:

- Mentoring is ensured by default by the PATT's Institute Director. Soon after arrival, the PATT and Institute Director discuss and choose a mentor (from across EPFL). The PATT decides if a mentoring relationship is worthwhile, i.e., it is not mandatory.
- In the first year after arrival, the junior faculty member is introduced to the ENAC School Council, to the Professional Associations, to the ENAC Direction, and to the whole ENAC community at the annual General Assembly. The ENAC Research Day is also promoted as a place to meet colleagues from other fields.
- EPFL has recently set up a management training program, entitled Management for Leaders in Science, which is targeted at PATTs. This mandatory program is specifically tailored for their needs. Initial feedback on the program is positive.
- EPFL's Teaching Support Center ([CAPE](#)) provides different types of workshops to help all EPFL teachers, including PATTs, to develop their teaching skills. CAPE also organizes welcome days for new professors called Bootstrap Days. CAPE provides in-depth analysis of courses, which can be requested for every course, should the PATT request it.

Despite these measures, a possible concern is the mentoring and integration of PATTs located at the ENAC antennas of Fribourg and Sion. At present, there are no PATTs at Sion, but it is expected that new appointees will be located there by 2020, or earlier. For these junior faculty (and their research groups), we recognize the increased difficulty of integration and collaborations. Isolation is a major risk, and it is addressed by the attention of Institute Directors, as well as regular reviews by the ENAC Direction. The annual PATT

evaluations – where each PATT is assessed by tenured professors, with feedback from the Dean and relevant Institute Director (section 3.2.3) – provide a level of scrutiny and interaction to detect potential issues. Note that, in addition to isolation, access to equipment and facilities for research is also a concern. However, the antennas are generally well equipped, as are the PATT's facilities. More generally, lack of access to equipment is more readily identified and resolved.

3.4 Promotion of Gender Equality

ENAC's emphasis on improving gender balance in its faculty is displayed by its recruitment procedures, starting with Search Committee Chairs, who engage in implicit bias training and are responsible for maintaining gender bias awareness during searches.

An initiative of ENAC is its Gender Equality Working Group (ENGW), a committee tasked with increasing the number of women faculty members. The main activity of the group is to actively seek women candidates for open faculty positions. In addition, a representative of ENGW is included in each faculty search committee in order to keep the issue of gender at the forefront. Since its inception in 2014, the group has participated in 20 searches.

The proportion of women faculty at ENAC is increasing. In 2011, ENAC counted 6 women professors (12.0%), with 2 POs (7.4%), 1 PA (7.1%), and 3 PATTs (33.3% of all Assistant Professors). At the end of 2018, there were 10 women professors in ENAC (16.4% of all professors): 4 POs (12.5%), 4 PAs (19%), 2 PATTs (25%), plus 1 PTIT (joint with Eawag). Of the 11 faculty searches completed successfully since 2014, 3 women were hired, a 27.3% rate of women faculty hiring.

In 2014, one of the faculty searches was designed as an active measure to increase the number of women faculty and was a dedicated women-only search. Based on a survey of women professors at EPFL, a critical mass of women professors would be achieved if their number represented a percentage of 35.8 +/- 9.1%. To achieve that goal at the current rate of ~30% of the hires being women would take approximately 15-20 years. Hence, future calls of this nature may be considered to achieve a more rapid increase in the relative number of women professors.

EPFL-wide, the Gender Equality Office is very active in promoting gender equality, including among faculty members. It has proposed guidelines for search committees and organizes the abovementioned implicit bias training for Deans, Institute Directors and Vice-Presidents, all individuals who are likely to chair faculty search committees. Many have taken the training and, for instance, the ENAC Dean explicitly raises implicit bias during each search. Another measure in the guidelines is the inclusion of at least two women (or an equal proportion depending on how many candidates are retained) on the short list of the candidates to be interviewed.

A new dual career hiring policy is in preparation (to replace the current ad hoc arrangement). It would allow for a central fund that supports dual career hiring. The mechanism is through the provision of bridge funding for the partner's salary while the relevant EPFL School or other University adjust their budget to include such an unexpected hire.

Additionally, a commission on the status of women faculty at EPFL was recently set up by the EPFL President and will investigate all relevant aspects of life as a woman faculty at EPFL. The goal of the commission is to carry out a quantitative and qualitative comparison (through the collection of data from the administration and through interviews) of professors in order to address any issues related to resources or work environment.

In summary, there are numerous activities aimed at tackling the issue of gender equality among faculty members in ENAC. It is expected that with continued efforts (particularly those targeting excellent candidates for positions) and with an EPFL-wide awareness of gender equality issues, implicit bias will continue to be actively counteracted and the relative number of women professors at ENAC will continue to increase.

4. Education

4.1 Overview

ENAC offers comprehensive programs in each of its disciplines of Architecture, Civil and Environmental Engineering at all levels (Bachelor, Master, PhD). The Bachelor (BA) and Master (MA) programs are each organized and administered by teaching Sections (SAR, SGC, SSIE) that are aligned with their respective research institutes (IA, IIC, IIE). The Master programs all lead to externally accredited degrees. EPFL follows the Bologna Accord, and offers its Bachelor-Master programs in a 3 year + 2 year format. The Bachelor and (with suitable prerequisites) Master programs can be taken at different institutions, encouraging mobility and choice. Since its inception, ENAC has had a mandated interdisciplinary component that brings students from the three Sections together, often in intensive cooperative educational settings. Graduates from ENAC programs thus are equipped with domain-specific professional training as well as interdisciplinary perspectives and project-based team working skills.

PhD programs at EPFL are offered across the entire institution. The numerous (and specialized) doctoral programs are administered by the EPFL-wide Doctoral School. Professors can be affiliated with different doctoral programs, depending on their research interests. Doctoral programs most closely associated with ENAC are, in order of size in the faculty, Civil and Environmental Engineering (EDCE), Architecture and Sciences of the City (EDAR), Mechanics (EDME) and Robotics, Control, and Intelligent Systems (EDRS). The doctoral programs administer all aspects of the PhD program, including PhD student admittance and progress throughout their doctoral studies, as well as doctoral mobility programs. For instance, within the EDCE doctoral school, there are established mobility awards offered to PhD students on a competitive basis. These awards foster multidisciplinary collaborations with leading academic institutions from around the world. Career prospects for ENAC PhD graduates include a balanced blend of academic and high-profile industry positions.

4.2 Bachelor and Master Programs

4.2.1 Background

ENAC offers Bachelor's and Master's degrees in Architecture (AR), in Civil Engineering (GC) and in Environmental Sciences and Engineering (SIE).

As noted above, Switzerland is a signatory to the Bologna accords, which define a common structure for higher education programs throughout Europe. This structure is composed of a first cycle of 180-240 ECTS ([European Credit Transfer and accumulation System](#)) course credits (3-4 years of study, respectively), which leads to the Bachelor title, and a second cycle of 90-120 ECTS (1.5-2 years of study), which leads to the Master degree, and a third cycle (with no ECTS constraints) leading to the doctoral degree. One of the goals of this framework is to facilitate mobility between the Bachelor and Master cycles.

In the case of EPFL, these two cycles replaced a 4.5 years course of study leading to a Diploma of Architecture or Engineering. The 180-ECTS EPFL Bachelor is not a professional

degree and almost every Bachelor graduate pursues a Master's degree either at EPFL (120 ECTS in ENAC) or at another university. All degree programs are full-time.

Terminology – In EPFL Masters programs, a [specialization](#) is a set of courses allowing students to gain deep knowledge in a specific sub-domain of their discipline (Major). A specialization requires passing 30 ECTS credits during the Masters. A [Minor](#) consists of a group of both compulsory and optional courses offered by one or several Sections (disciplines). Disciplinary and transdisciplinary Minors are designed to provide flexibility and depth in the education of its engineers. Interdisciplinary Minors either tackle a multidisciplinary topic or offer complementary education to the traditional engineering curriculum, thus opening up educational and career prospects. Every educational domain offers a disciplinary Minor to students of other disciplines. Students have the option to include one of these Minors as part of their curriculum.

4.2.1.1 Interdisciplinary Courses, Projects, Contests, Entrepreneurial Spirit

ENAC has been particularly active, since 2002, to promote the [Design Together](#) program (section 4.4.1). This consists of courses and projects from the Bachelor to Master levels allowing students from AR, GC and SIE to experience interdisciplinarity in different fields. The principle of Design Together is to have ENAC students work cooperatively on issues of a multidisciplinary nature to prepare them to deal with complex challenges in their future professions. This proactive type of learning leads to the implementation of innovative projects in which the consideration of diverse perspectives and skills is an important asset in creativity and entrepreneurial spirit. Activities promoting interdisciplinarity include:

- The Solar Decathlon (section 4.4.2), a competition where the construction of a full scale, operational, solar-powered pavilion was designed by the students themselves, with the advice of academics and professionals. The students gained a hands-on educational dimension that inspired an innovative professional approach, supporting the process of co-creation of homes and cities of the future.
- The Student Kreativität and Innovation Laboratory (SKIL, section 4.4.3), an environment that allows students to engage in hands-on, self-defined projects in a dedicated workshop setting. Students work together in small groups on their own ideas, with access to a wide range of tools, materials, software, etc., assisted by specialized coaches.

- Projects at the Bachelor and Master levels (e.g., design projects in SSIE) where students are encouraged to carry out their individual or group projects as independently as possible.

ENAC also offers the possibility for any Masters student to tackle a multidisciplinary topic (also within the Design Together program) or, as mentioned, to pursue interdisciplinary Minors that complement the engineering curriculum. ENAC offers two Minors, the first, Territorial Development (DTU), was recently reformulated as Urbanism in Transition (UT). The second ENAC Minor is Integrated Design, Architecture and Sustainability (IDEAS). Any Masters student may alternatively choose a disciplinary Minor proposed by another EPFL Section and that is generally recommended by the Section to which the student is affiliated. Currently, 15 [disciplinary Minors](#) are offered at EPFL.

To specifically develop professional engagement, ENAC degrees include internships in companies, the implementation of semester or Master projects in collaboration with companies, the use of external lecturers from companies or design offices and alumni participation as experts during student project defenses. Furthermore, at the end of the Bachelor cycle, a study trip complements the degree. Students have the opportunity to visit abroad monumental projects, review their technical particularities with an attentive mind and link the fundamentals they learnt in class with practical applications outside a normal class setting.

4.2.1.2 Accreditation and Rankings

Since 2006, like many of the best technical universities in the world, EPFL opted for dual recognition of its quality assurance, i.e., at both at the institutional and at the education program levels, through regular quality audits and accreditation of the degree programs.

With respect to engineering degrees, since 2007 the French Commission for Engineering Titles (CTI) has evaluated all EPFL engineering programs according to its Quality Assurance and Professional Standards. The CTI has longstanding expertise in the accreditation of engineering degrees, and actively promotes the title and profession of engineer in France and internationally. Having an engineering title au-

thorized by the CTI facilitates the professional integration of EPFL alumni who pursue their career in industry outside Switzerland.

CTI standards, which are akin to that of the Baldrige [National Quality Award](#) in the US for excellence in education, cover the activities of the entire institution. Particularly, all EPFL Masters programs with a professional engineering title are conferred with accreditation by the CTI and the AAQ (Swiss Agency of Accreditation and Quality Assurance), as well as the European label, [EUR-ACE](#), for which most programs are validated until 2021. The Masters in Architecture is also accredited by the AAQ.

4.2.2 Architecture

4.2.2.1 Introduction and Objectives

Training future architects by giving them a solid polytechnic background is the key role of the Architecture Section (SAR). The Bachelor years form a common base, the Master phase completes the students' academic development. Among other things, the program implants a vision that embraces both the contemporary realities of architecture and its ancient roots. In a polytechnic culture, the program is seen as an art and a craft, to be practiced with intelligence, passion, and experience, drawn from many spheres of scientific knowledge.

Training in architecture is articulated through three main approaches:

- Use and experimentation with a broad range of construction techniques
- Knowledge of both history and theory
- Acquisition of an expressive individual consciousness that is in phase with collective needs and aspirations

All three approaches form an inseparable trinity: They cut across every architectural design project and they carry the core of commitments and interests of the teaching program.

In this way, the polytechnic architect's acquired skills are constantly verified within the project, an independent experience that marshals advanced techniques, human and social sciences, and the expressive arts.

For the student, the architectural project is the catharsis by which he or she experiments with and gives form to what has been learned. By giving central priority to the project and its cultural dimension, SAR aims to qualify future architects who are equipped with great intellectual independence, solid ethical principles, and a structured methodological approach. The program is designed to educate professionally qualified future architects who are capable of giving form to their ideas in an independent and informed manner.

Today, more than ever, ensuring that the next generation of architects has a sound sense of environmental sensitivity is vital to their training. This can only be achieved by nurturing an inquiring, critical spirit capable of facing the big issues of our day and age: sustainable urban development, efficient use of materials, simplification of techniques, interaction between traditional know-how and advanced technology, social compatibility, and in general the intelligent use of resources.

4.2.2.2 Curriculum

Architecture has always been a complex discipline that merges the three great domains of human knowledge and imagination, science, culture and art. Architectural design recognizes the dynamic imbalance between all three, and the novice architect has to forge a stance using technique, intelligence and a sense of poetry between all three to maintain equilibrium. This is why the general cultural trunk of our teaching is devoted to discovering the basics of architecture. The great prerogative of architectural training is that it favors the humanities, and by this it differs from the purely technical disciplines, which from the outset demand a specialized apprenticeship in their component subjects.

For a trainee architect, the first year of basic training is an architectural design studio. The student is straightaway immersed in his or her future discipline, introduced to the technical and cultural tools-of-the-trade. This precedence given to the architectural project and to the subjects and skills directly related to it is a treasure to be jealously guarded, nurtured, added to and shared.

A polytechnic architect must acquire solid intellectual skills and learn how to put them into practice, not just with consciousness and ease, but also with the sensitivity of his

or her own talent. Excellence does not require mere expertise in manipulating forms and materials. It demands an independent spirit capable of drawing inspiration from personal feelings, able to bring to bear real life experiences, and give expression to original intuitions. To this end, affirming the principle that both poetic and intellectual dimensions must inform all architectural training, SAR dispenses a thorough teaching of theory and history during the three Bachelor years, followed by a course entitled [Visions and Strategies](#) at Master level. This course is a set of lectures structured with an eye to developing our students' awareness of the major issues facing architects today, which they formulate in their theoretical statement during their final Master year.

The course focuses on theory and gives novices the cultural instruments that will enable them to hone their own way of seeing things and interpreting them. Organically, the project appears as an intellectual construction shaped by instruments specific to architecture. What is more, throughout the two Master years this cultural vision of the project also underpins the structure of the [Orientations](#) course (Figure 4.1), which groups themes that address major issues surrounding architecture, and gives students the possibility of rounding out their workshop project.

Teaching in SAR is organized in such a way as to reinforce specific characteristics, which enables us to not only to define the profile of each teacher, but also to develop what each one contributes. With this approach, the Orientations course at the Master level thus satisfies two objectives. First, it orients students more clearly according to different theme headings and, second, it fleshes out the cultural dimension of each theme by way of associated modules and teaching units.

A characteristic of the program is that Master's diplomas are awarded after completion of two criteria: the theoretical statement and the Master project. Distinct by nature – one intellectual, the other practical – these criteria guarantee each student's level of proficiency. Every candidate must complete, individually, both a study and a project of his or her own choosing.

The complete SAR program is displayed in Figure 4.1.

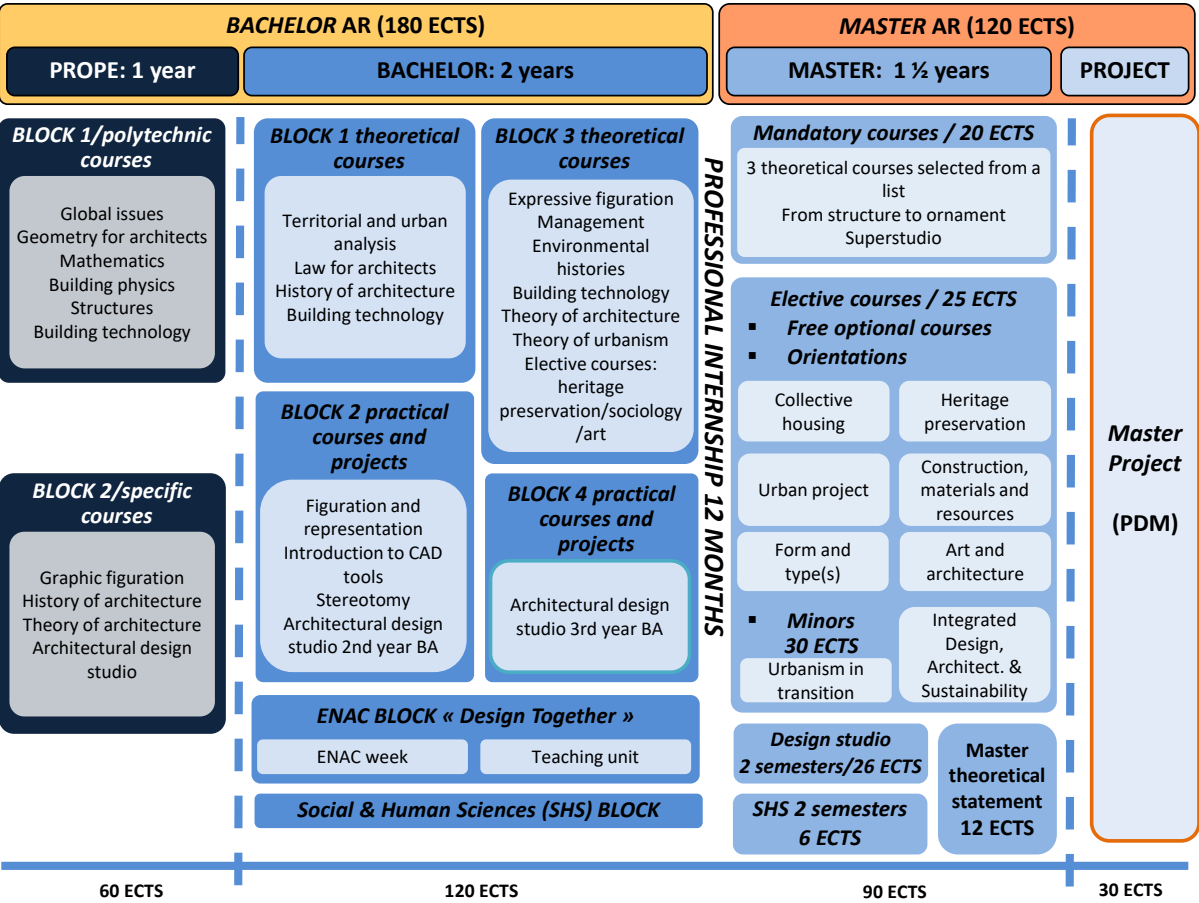


Figure 4.1. Outline of the Bachelor/Master program in Architecture.

Bachelor Program

Foundation Year

Architectural design and draughtsmanship
Science and technology, parametric design
Theory and history
Humanities and social sciences

Bachelor Curriculum

30%	Studio	33%
54%	Computer representation and modelling	10%
13%	Science and technology	20%
3%	Theory and history	13%
	Urban and spatial planning	6%
	Humanities and social sciences	6.5%
	Core courses (law, management)	5%
	Design Together	6.5%

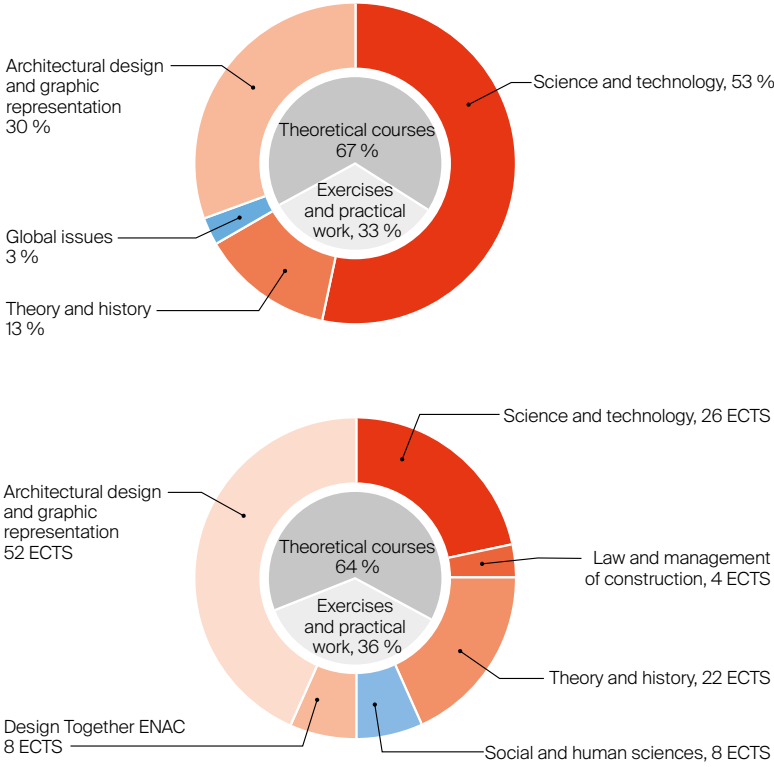


Figure 4.2. Simplified architecture study plan at the Bachelor level, year 1 (upper image) and at Bachelor level, years 2 and 3 (lower image).

Foundation (propaedeutic) Year

The foundation year (60 ECTS) includes two blocks of subjects, the first of which groups all the scientific and technical subjects, which are decisive among other things for calculation of the average mark to succeed at the end of the first semester (at least 3.5 is needed to progress to the second

semester, less than 3.5 leads to a specialized course to equip students to succeed in the first year at the second try). The second block includes subjects specific to the discipline such as architectural design, graphic figuration, history and theory of architecture.

Bachelor Cycle

The Bachelor cycle (two years, 120 ECTS) comprises two blocks per year of theoretical subjects on the one hand, bringing together all theoretical, historical, construction and urban disciplines and, on the other hand, practical courses with architectural design and subjects relating to computer representation and modeling. Two cross-disciplinary blocks complement the Bachelor cycle: the ENAC subjects of Design Together and the various transversal Humanities and Social Sciences subjects taken by all EPFL students.

Representation and Modeling, Parametric Design, CAD in the Bachelor Program – During their studies in architecture, students acquire skills and knowledge in the essential field of representation and modeling. This comprises different approaches that allow students to develop a personal language using the appropriate means at their disposal. Each year they are required to perfect both the essential manual techniques (sketching, freehand drawing, observational drawing) and the necessary digital techniques for architectural design, its representation, the preparation of documents required for prototyping, up to management of the project itself.

In the foundation year, the Graphic Figuration course (4 ECTS) teaches observational drawing and various representation techniques by hand, including the notions of perspective and rendering of surfaces and shadows. The Geometry for Architects course (6 ECTS) deals with problems associated with shape generation and geometry more generally as a privileged subject of parametric design software, while addressing the historical and cultural dimension, along with the technical and mathematical aspects essential to the architectural design process.

In the second Bachelor year the courses on Introduction to CAD tools in architecture and Stereotomy (4 ECTS for both courses) allow students to become familiar with the main 2D and 3D representation software tools, and to understand the related mechanisms and principles so that they can then practice and deepen their skills in the field, particularly through the representation of their own projects. A series of complete tutorials guarantees training on the different software tools, with a contact lecturer for each program. The Stereotomy course approaches geometry through the current digital and parametric tools, including a glimpse of computer-aided design and manufacturing.

The course on Principles of Architectural Gestaltung (4 ECTS) deals with architectural surveys and their direct relationship with built architectural objects and their representation, with the classical techniques of in situ surveys, freehand then computer-assisted drawing, and finally a model. The close relationship to buildings is highlighted through the choice of vernacular constructions as the subjects of these surveys.

In the third Bachelor year, the Expressive Figuration course (4 ECTS) deals with the theoretical foundations and operative techniques of representation, allowing students to define and convey an architectural idea in its concrete expression. The relationship to art serves as a guide: Expressive techniques belonging to the field of art are considered as the mirror of the architect's logical and formal operations and become operative tools for the students.

Various program related to representation are also offered as part of the ENAC courses – ENAC Weeks or Learning Units.

Building Technology in the Bachelor Program – The Bachelor curriculum's Construction, Building Physics and Structures courses are grouped into a single subject for which the various lecturers coordinate their contributions. For several years, it was evident that the students had difficulty in integrating these different disciplines and the construction and structural dimension of buildings into their projects. In 2018, these three disciplines were grouped to improve coordination, particularly to integrate different elements and avoid compartmentalization.

The first semester of each academic year is devoted to theoretical courses in the various disciplines, with practicals included where appropriate. The second semester of each academic year integrates the different subjects and is devoted to practical parts of students' personal work, with supervision provided by architects from industry and by the lecturers themselves based on a mentoring/tutoring model. A long-term exercise occupies students throughout the semester. This demands the development of a series of drawings describing the construction process of a building of increasing complexity year after year. Students improve their understanding of the inseparable link between construction and design, and the necessary integration of the structural, constructive, material and physical components of buildings.

Internship

Between the Bachelor and the Master, students carry out a 12-month full-time practical internship in an architectural firm. This period of direct contact with the profession allows them to complement their training, especially in the areas of construction, project management, mastering various IT representation tools, and 2D and 3D modeling. The reports submitted by the students and the evaluations by the firms show how important this period of professional practice is in developing managerial and entrepreneurial competences, improving transversal skills, and knowledge of the building processes.

Master Program

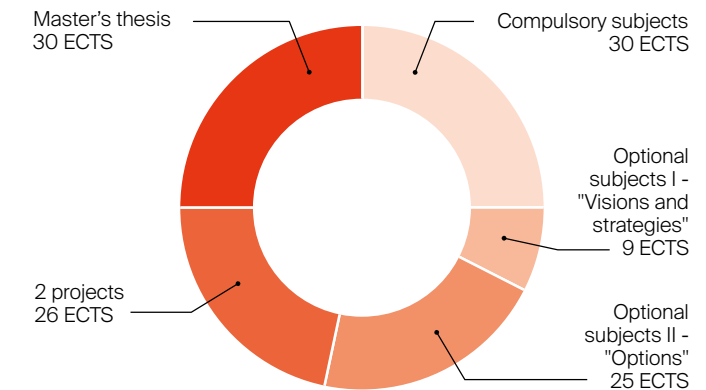


Figure 4.3. Simplified architecture study plan at Master level, years 4 and 5.

The Master cycle (90 ECTS) includes 4 groups of subjects. The first group of subjects offers theoretical approaches relating to the field of theory and history of architecture, art, aesthetics and ethics. These are followed by compulsory courses for all students:

- Humanities and social sciences
- Master Project Theoretical Statement (first step of the Master project)
- Superstudio – module bringing together all students in the year for a semester project and introduction to research
- General theoretical course – From Structure to Ornament

In addition, all students must complete two semesters of architectural design during their Master curriculum. Finally, optional courses offer a wide range of various types of teaching, including cross-disciplinary thematic modules. The theoretical courses cover various fields in connection with the different orientations proposed for the Master degree: architectural design and urban and spatial approach, theory and history of architecture, construction and structures, preservation, social sciences, modeling and representation.

Representation and Modeling, Parametric Design, CAD – At the Master level, several courses are proposed as in-depth studies in the field of representation and modeling:

- Teaching units: Graphie, Cartography, Art and Architecture, discussing different theories and techniques of digital and manual representation, including the use of photography and mixed techniques of collage and others
- Theoretical courses in the field of art and representation

The basics of BIM (Building Information Modeling) are taught at Master level through:

- A one-semester theoretical course
- An in-depth teaching unit
- Hands on experience with an innovative platform that demonstrates BIM through landmark case study projects (currently being developed)

Courses in building physics, construction, sustainable approaches related to comfort in buildings and interventions in an existing context:

- Use of measurement and diagnostic software for space quality, heating, ventilation, thermal balance, daylight and artificial light
- Synthesis and analysis of monitoring data, as well as their use in sustainable design

Master-level Architectural design studios:

- In specific studios, use of parametric tools and technologies in design thinking, at architectural, urban and territorial scale, study of form-generating processes using of algorithmic and parametric tools
- Use of parametric tools in order to build physical models representing structural fragments and details

During the Master program, students choose an orientation comprising an architectural design studio, a teaching unit and a theoretical course around a common theme. Current orientations include:

- Collective housing
- Urban design
- Preservation and heritage
- Form and typology
- Art and architecture
- Construction, materials and resources

At Master level, students may also choose to take a Minor (discussed above) rather than optional courses.

The Master project (30 ECTS) requires students to develop their own theme, issues and methodology for their project, and to select the members of the monitoring group (two professors and a lecturer from among the EPFL scientific staff or faculty). The Master project lasts an entire term and is preceded by the drawing up of the Master project theoretical statement, in connection with the project to follow. These two interdependent parts form a whole, giving students the opportunity to experience, over the course of an academic year, a holistic approach from initial documentary research to materialization of the project to be presented and debated in public before a jury.

4.2.2.3 Quality of the Program

Committees

Structures to Monitor Education – The Architecture Section has a Teaching Commission bringing together, in addition to the Section management, representatives of the faculty (professors and lecturers), scientific staff and students. The Commission meets three times per semester and deals with all matters relating to teaching, in particular the study plan, which it must validate each year prior to submission to the ENAC Management and Section Directors' Conference, and ultimately to the Presidency.

The Professors' Conference meets eight times a year, and also deals with the main issues related to teaching, as well as those related to research, relations with other institutions and future recruitments. A session outside the campus at the beginning of the academic year provides a whole day to deal in depth with matters relating to the organization of the school and the strategy for the future development of education and research.

In July, an important session closes the academic year with a discussion on the marking of Master projects, which ensures a fair and concerted processing of borderline cases, as well as of all evaluations.

The system for the appointment of external experts for Master projects was changed in 2018, allowing the program to

utilize the expertise of six to eight people from academia and industry, chosen by the members of the Professors' Conference. The experts write a report on the jury sessions they have attended, the skills and shortcomings they noticed in the students, and make suggestions for education and supervision according to their own experience.

Other Contacts in the Field of Education – Each year in August, the Section Director attends the meeting of the European Association for Architectural Education (EAAE). On this occasion, each school contributes to the debate through a presentation or written contribution. The exchanges make it possible to confront and draw inspiration from the various educational systems.

In addition, the Architecture Section is a member of the *Architekturrat der Schweiz* (Architectural Council of Switzerland), which brings together all Swiss schools of architecture, institutes of technology and universities of applied sciences, the Swiss Society of Engineers and Architects and the Federation of Swiss Architects, (which organizes regular thematic meetings on education and research in architecture).

These different contacts with representative bodies of educational institutions at all levels encourage the necessary dialogue and questioning of certain aspects of education. These enriching exchanges allow us to position ourselves as a school in a varied geopolitical and cultural context, to

understand the specificities that our courses must continue to offer, and to anticipate the necessary adjustments to the curricula.

Benchmarking

Academic and Professional Recognition of the EPFL Architect Degree – Europe and Switzerland – The EPFL Master's degree in Architecture is acknowledged both academically and professionally at the European level. This recognition, obtained in 2011 by ensuring compliance of the curriculum with Article 3 of European Directive 85/384/CEE of 10.6.1985, guarantees the automatic validity, without further checking, of the Masters in Architecture as an academic qualification as well as professional accreditation within the European Union. In Switzerland, Masters in Architecture is valid for professional registration with the Swiss Register of Architects.

In either case, at both of these levels, the applicable criteria may be summarized as follows:

- Awareness and understanding of the social role of architects
- Ability to design architectural projects meeting functional, construction, technical, cultural and social requirements
- In-depth knowledge of the history and theories of architecture, art and related humanities
- Understanding of structural and construction design issues
- Ability to understand spatial development, knowledge of urban and spatial design theories, knowledge of planning processes
- Appropriate knowledge to ensure sustainable development and respect for the environment, as well as the comfort required by users
- Ability to take into account regulatory and financial aspects, in accordance with the needs of the user.

Through the combination of the various subjects of the Bachelor curriculum, studied systematically, and of the Master courses studied in a more specific and in-depth fashion by the students, all these fields are dealt with and contribute to feed the architectural design process in gradually more and more complex dimensions, up to the Master Project – the personal and autonomous work of the student crowning the architect's training.

Enrolment

The Architecture program has traditionally had a large student enrolment compared to the other ENAC programs of the ENAC faculty. In the last 8 years the number of students in the propaedeutic year decreased, however, from 360 in 2012 to 220 in 2018. However, the overall enrolment in Bachelor and Master degrees in architecture has steadily increased over the past 20 years, from about 580 students in 1998 to about 1150 in 2018. Each year, between 10 and 20 students from other universities join the Master program.

Professional Integration and Career Satisfaction

According to the most recent inquiry on professional integration and career satisfaction by EPFL's career center, the Alumni feedback shows that the lowest satisfaction with the degree concerns salaries. This is a well-known situation when salaries for new architects are compared with corresponding salaries for other scientific and engineering professions. Otherwise, the general satisfaction degree is good, particularly concerning tasks performed.

4.2.2.4 Teaching Resources

Future Challenges – In the period to 2025 a whole generation of professors currently engaged in several fundamental areas of our education will be retiring:

- Architectural design: 6 professors, including 4 full professors
- Theory of architecture: 1 full professor
- History of architecture: 1 full professor
- Preservation and heritage: 1 associate professor
- Geometry, BIM, parametric teaching: 1 associate professor
- Building physics: 1 full professor
- Urban planning: 1 full professor
- Sociology, architecture and development: 1 senior scientist (MER), 1 associate professor
- Structures: 1 full professor.

The Section and Institute of Architecture will take the opportunity to redefine the shape our education in the current and future academic landscape.

Infrastructure, Models, Logistics – All architectural students have a studio workstation assigned to them for the semester. All the studio premises are grouped around the SG building, with the exception of a few satellite workshops located in the nearby Triades neighborhood, or in the GC building. The need to be able to guarantee a workstation for each student is a valuable way to take advantage of different opportunities, even across a relative spread of premises.

The model workshop and prototyping infrastructure complement the offer for students, who produce a large number of models each semester.

Students also have a computer room equipped with the software they need for their courses and projects, and a room with plotters that allows them to prepare their deliverables throughout the semester. The EPFL Print Center also offers plotting facilities.

Some time ago the Section requested additional premises to conduct manual activities (stone cutting, large format painting), the construction of large-size prototypes, a place suitable for pouring concrete or assembling construction parts. Neither the studio premises nor the classrooms are suitable for this type of activity, which is why various locations on the campus are used, taking advantage of the opportunities that arise depending on available space and ongoing projects.

4.2.2.5 Anticipated Curriculum Evolution

The previous analyses of the Section's study plans, both at the level of the last audit and of accreditation of the Master curricula, have shown a degree of fragmentation of the various courses, which is not conducive to coherent learning. It is foreseen that the current study plan for the Bachelor will undergo a series of course groupings that will allow students to learn better, on the one hand, and to foster more consistency and coordination between neighboring and complementary disciplines on the other. The following changes are expected:

- Concentration of the Mathematics and Building Physics courses in a single semester in the foundation year
- Concentration of the History of Architecture and Theory of Architecture courses in the Bachelor curriculum – second year for History and third year for Theory
- Concentration of urban planning courses in the Bachelor curriculum (second and third years)
- Consolidation of the Construction, Building Physics and Structures subjects into a single discipline – Building Technology – in the Bachelor curriculum (second and third years).

History and Theory of Architecture – The history and theory of architecture courses are concentrated in specific semesters rather than being spread over every semester in the Bachelor curriculum, in order to encourage more in-depth and targeted learning, and to reduce the number of tests for students in the various examination sessions.

In the foundation year, the history course will be concentrated on the spring semester, in order to free up time during the autumn semester, which includes all the subjects which are decisive for continuation of the foundation year, or for the upgrade course in case of insufficient marks. Thereafter, the history of architecture courses will be concentrated in both semesters of the second Bachelor year, while the theory of architecture courses will be concentrated in both semesters of the third Bachelor year. The total number of course credits for these two subjects does not change.

4.2.3 Civil Engineering

4.2.3.1 Introduction and Objectives

The 5-year Master of Civil Engineering offered by the Civil Engineering Section (SGC) provides highly specialized knowledge corresponding to Level 7 of the European Qualifications Framework and, at the Second-Cycle Level, to the EUR-ACE Framework Standards. This is directly confirmed by the number, quality and diversity of the final-year [Master projects](#) that are at the forefront of either current scientific research or that represent state-of-the-art collaboration with industry. Descriptions, including objectives of the Master program in civil engineering are published on the following websites:

- [Prospective students](#)
- [Bachelor students in civil engineering](#)
- [Master students in civil engineering](#)
- [Civil Engineering Section](#)

The primary objective of the Master program is to create high-level general civil engineers who possess top skills in a broad range of domains such as structural engineering, mechanics of materials, hydraulics and energy, geotechnics as well as transportation and mobility. Master students obtain deep knowledge through choosing one of these domains as a specialization. Interdisciplinary training is accessible through Minors, for example in [Computational Sciences](#) or in [Management of Technology and Entrepreneurship](#).

Civil engineers work in multidisciplinary and often multicultural teams at the international level. An ENAC priority is interdisciplinary education involving collaborative projects by students of civil engineering, architecture and environmental engineering, within the frame of the [Design Together](#) program.

4.2.3.2 Curriculum

The civil engineering curriculum follows European guidelines, and is structured as a Bachelor of 180 ECTS followed by a Master program of 120 ECTS (Figure 4.4). Information on study plans and regulations, course schedule and workload, and teaching methodology, is publicly available on the [academic-services website](#) and on the Section [website](#).

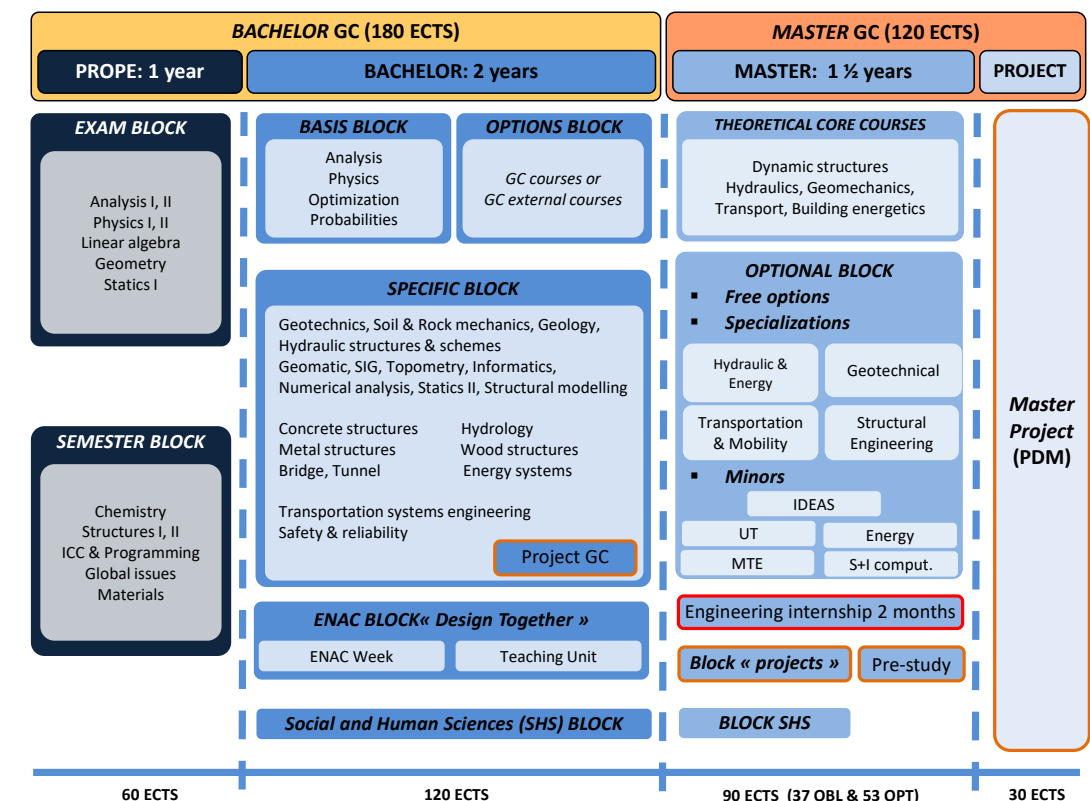


Figure 4.4. General scheme of the Bachelor-Master of Civil Engineering curriculum (180 Bachelor ECTS, 120 Master ECTS).

Bachelor Program

As summarized below (Figure 4.5), the Bachelor of civil engineering places an emphasis on basic sciences, together with the essentials of statics, structures and mechanics. Throughout their studies, students complete [a program in Social and Human Sciences \(SHS\)](#), providing them with an awareness of global issues, and a broad range of transversal and cultural skills that are essential for their future insertion into the professional world.

Multidisciplinary courses (ENAC courses) and more specific courses in the four domains of civil engineering are introduced during the second and third years where they are coupled with exercises and projects and, in the third year, with a 6 ECTS Bachelor project. During the third year, students take 7 ECTS as optional pre-orientation courses to prepare for their future Master's degree.

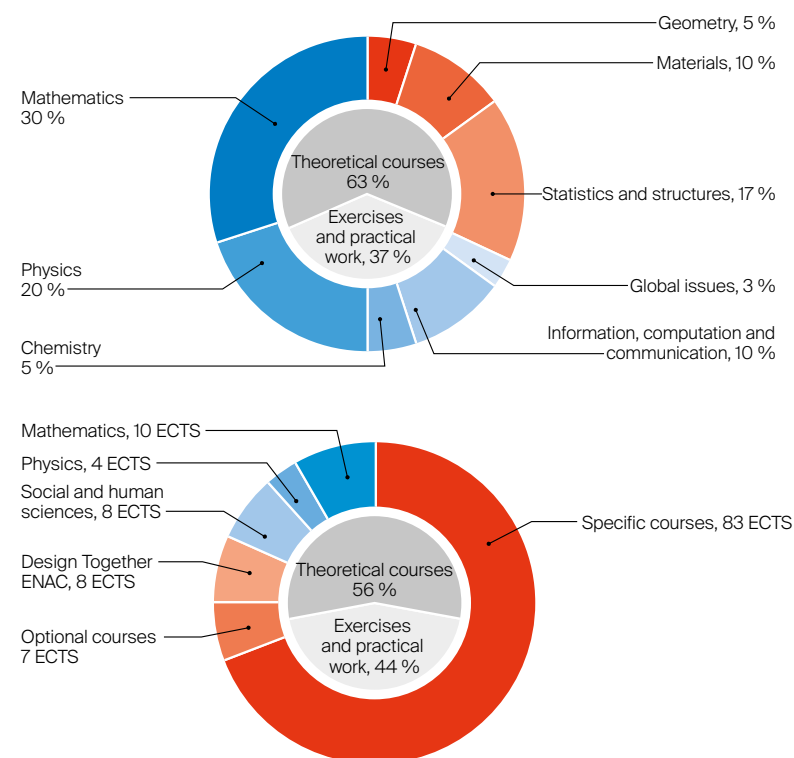


Figure 4.5. Simplified civil engineering study plan at Bachelor level, year 1 (top) and at Bachelor level, years 2 and 3 (bottom).

In terms of credits, the courses presently offered in the second and third years of the Bachelor degree belong proportionally to the fields of structural engineering (25%), geotechnics (10%), hydraulics and energy (11%) and transport (6%). The remaining 48% are either core or interdisciplinary courses.

Master Program

As indicated in Figure 4.6, the [Master program in civil engineering](#) is composed of five entities that are organized as follows:

- A core-course block of civil engineering (obligatory, 12 ECTS).
- A group of optional courses in civil engineering or related topics (53 ECTS) from which students select a predefined set of branches to obtain a specialization (30 ECTS) in one of four domains: structural engineering, geotechnical engineering, hydraulic engineering and energy, as well as transportation and mobility. In terms of credits, the courses presently offered by the Section in this group of options belong proportionally to the fields of structural engineering (34%), geotechnics (14%), hydraulics and energy (16%) and transport (19%). The remaining is for 17% are transversal or interdisciplinary courses.

- A block of five obligatory semester projects (22 ECTS), four of which are civil engineering projects or laboratories and one related to humanities.
- A pre-study (3 ECTS) during the third semester to prepare the final Master thesis.
- A Master thesis (30 ECTS) preceded by an obligatory [internship in industry](#) that is not credited for but is a pre-condition to enter the Master project. This internship should last for at least 2 months. It is evaluated by a faculty member on the basis of a technical report and a standardized evaluation of the student by his/her tutor in the enterprise. Over the last 4 years, students have completed their Master degree project in the fields of structural engineering (49%), geotechnics (11%), transport and mobility (20%), hydraulics and energy (17%) and interdisciplinarity (3%).

Students can choose a [recommended Minor](#) (30 ECTS) instead of a specialization. Recommended Minors for the civil engineering are: [Urban Planning and Territorial Development](#), Integrated Design, Architecture and Sustainability ([IDEAS](#)), [Management, Technology and Entrepreneurship](#), [Energy](#) and [Computational Sciences](#). The selection of minor courses is done in agreement with the Minor program direction and the Section.

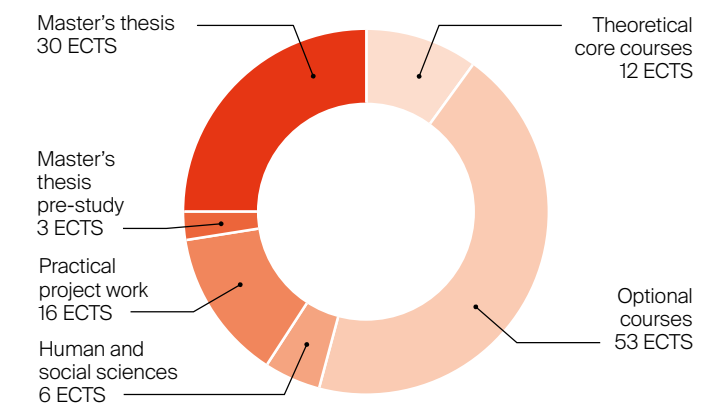


Figure 4.6. Simplified civil engineering study plan at Master level, years 4 and 5.

During the final Master semester, our students may be allowed to undertake [a mobility exchange to do their Master project](#) in another academic institution. This exchange must be accepted by the Section and the professor in charge of the Master thesis.

Also, a disciplinary Minor in civil engineering, with four orientations according to the student background, has been available to Master students from other EPFL Sections since 2010.

4.2.3.3 Quality of the Program

Each semester, all civil engineering courses are evaluated by our students. In Figure 4.7, the evaluation of all Bachelor and Master courses over the last 4 years is classified according to the negative response rate. It shows that the large part of our courses are very positively rated.

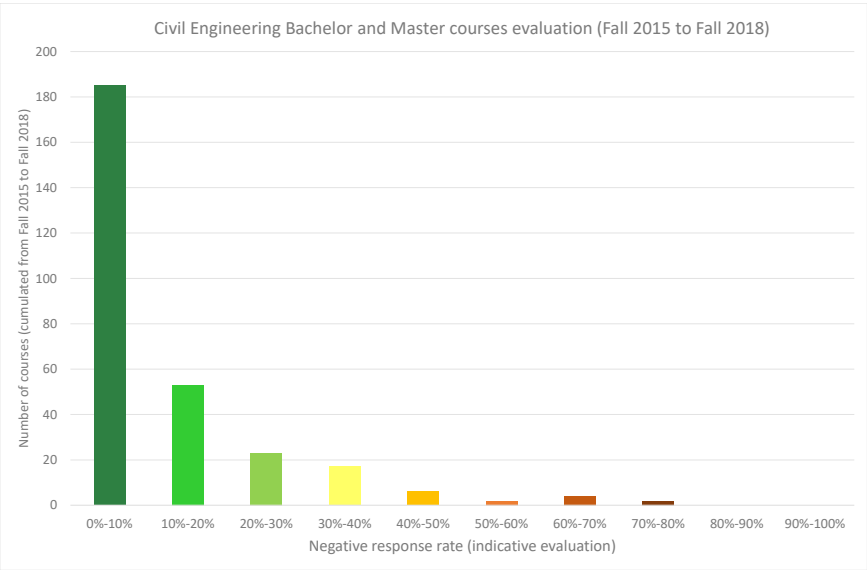


Figure 4.7. Cumulative results (Fall 2015 to Fall 2018) of the indicative evaluation for all Bachelor and Master Courses offered by the Civil Engineering Section.

Committees

The educational objectives of our program are evaluated and discussed on a regular basis by the various bodies of our school, in particular the [Teaching Commission of the Civil Engineering Section](#). All specific points concerning program evaluation and updates are treated by the Teaching Commission. General discussions or information on the educational programs also take place during the [Faculty Board](#) and [ENAC Management Board](#) meetings, with the members of the [Advisory Board of the Civil Engineering Section](#) and with the [Academic Commission](#).

Enrolment

The enrolment of students in quantity and quality for the Bachelor and the Master degrees is important to meet the needs of the profession and indicates the attractiveness of our curriculum.

The Section had a significant increase in the number of new Bachelor students from 2011 to 2013, stabilizing at 80 to 90 per year with a total number of Bachelor students of around 280 (Figure 4.20). The current number of annual Bachelor graduates is around 50 to 70, of which female graduates make up approximately 20% (Figure 4.20). On average, 90%

of our graduates continue their Master studies at EPFL.

Bachelor trends clearly influence the Master level with record student numbers (Figure 4.21) as shown in the following enrollment numbers: first semester of the Master (110 in 2015), all Master students (241 in 2016) and Master graduates (87 in 2017).

External candidates for the Masters is shown in Figure 4.22. The admission rate is 25% and the average percentage (over the last nine years) of candidates accepted but who did not attend is about 46%. Among accepted candidates, an average of 35% are from Swiss applied-science universities. Such candidates are by law automatically accepted after successfully completing a 60-credit (one year) selection program.

Professional Integration and Career Satisfaction

The professional integration of prospective civil engineering graduates is worth noting, as seen in Table 4.1 on job search effort and activity, over one year. Figure 4.27 also demonstrates that their satisfaction in their first job is high, based on all indicators for more than three-quarters of respondents.

Table 4.1. (Upper) Search effort for civil-engineering graduates. (lower) The type of activity for civil-engineering graduates in after one year of employment. Data: EPFL Career Center, November 2018. Graduation years from 2013 to 2016.

	Civil Engineering	EPFL
Average number of candidacies	10	15
Average number of job offers	1.9	1.6
Number of weeks of job search	9.6	11.5

	Number	Percentage
Employed	107	87.0
Independent	2	1.6
PhD	8	6.5
Searching for a job	2	1.6
Unemployed, not searching	4	3.3
Total:	123	100.0

4.2.3.4 Teaching Resources

The Civil Engineering Section relies on contributions of external and internal lecturers for about 20% of its core courses. These teachers do not have the same resources as regular professors (e.g., no research units, no doctoral students, no thesis projects). The Section anticipates further improvement of available experimental and IT facilities to meet today's teaching requirements. The number of well-equipped experimental spaces is sometimes insufficient to cope with

needs of students working on their Master thesis projects, although some spaces were recently upgraded.

Several retirements are anticipated in the coming years. New appointments will offer new possibilities for the teaching program, although not at the expense of continuing to provide the range of technical and professional expertise expected of for graduates.

4.2.3.5 Anticipated Curriculum Evolution

While student learning in core areas of civil engineering, such as mechanics of materials and infrastructure design, analysis and evaluation is well established, the Section is currently developing the following aspects of its curriculum to ensure that students are sufficiently endowed with scientific skills and technological ability to allow them to perform at a high-level in both the professional and academic worlds:

- Strengthening of computational thinking in its curriculum through the current and future introduction of courses at the Bachelor and Master levels. These are Information, Calculation and Communication (BA), Introduction to Computational Thinking (BA), Digital Representation/BIM (BA), Programming Concepts in Scientific Computing (MA), Deep Learning for Self-Driving Cars and Beyond (MA) as well as Bachelor and Master projects related to these fields.
- Strengthening of links with industry through the introduction of Master projects in companies and through organization by the Civil Engineering Student Association of an annual forum that allows students, alumni, design offices and companies to meet and exchange.
- The possibility of appointing Professors of Practice (section 3.2.6) to continue high-level teaching of subjects.
- With prospective nominations of new professors, it is anticipated that our program will be strengthened to address emerging needs regarding infrastructure digitalization and aging and renewable energy management.

4.2.4 Environmental Sciences and Engineering

4.2.4.1 Introduction and Objectives

The [program in Environmental Sciences and Engineering](#) (SIE) encompasses a Bachelor of Science of 180 ECTS and a Master of Science of 120 ECTS. It aims to deliver both the highly specialized scientific and technical competences needed to design innovative and effective engineering solutions to increasing environmental burdens, and the more transdisciplinary competences needed to provide technically feasible and socially acceptable solutions to complex environmental issues.

Within a fast-changing earth system, environmental engineers are expected to design new technologies (clean tech) and innovative solutions to environmental issues while:

- Improving the quality of life and preserving the availability and the quality of natural resources
- Assessing and mitigating risks and impacts of human-driven actions and of natural processes
- Collecting and synthesizing information on our environment across multiple scales and components to make decisions, to define policies, and to act at the interface between policy, industry, and citizens

Environmental engineers rely on a solid foundation in environmental and engineering sciences. Familiarity with new technologies (smart sensor networks, field robotics) and approaches (data science) is required. Softer competences are also necessary, including interdisciplinary thinking and systems-oriented approaches.

4.2.4.2 Curriculum

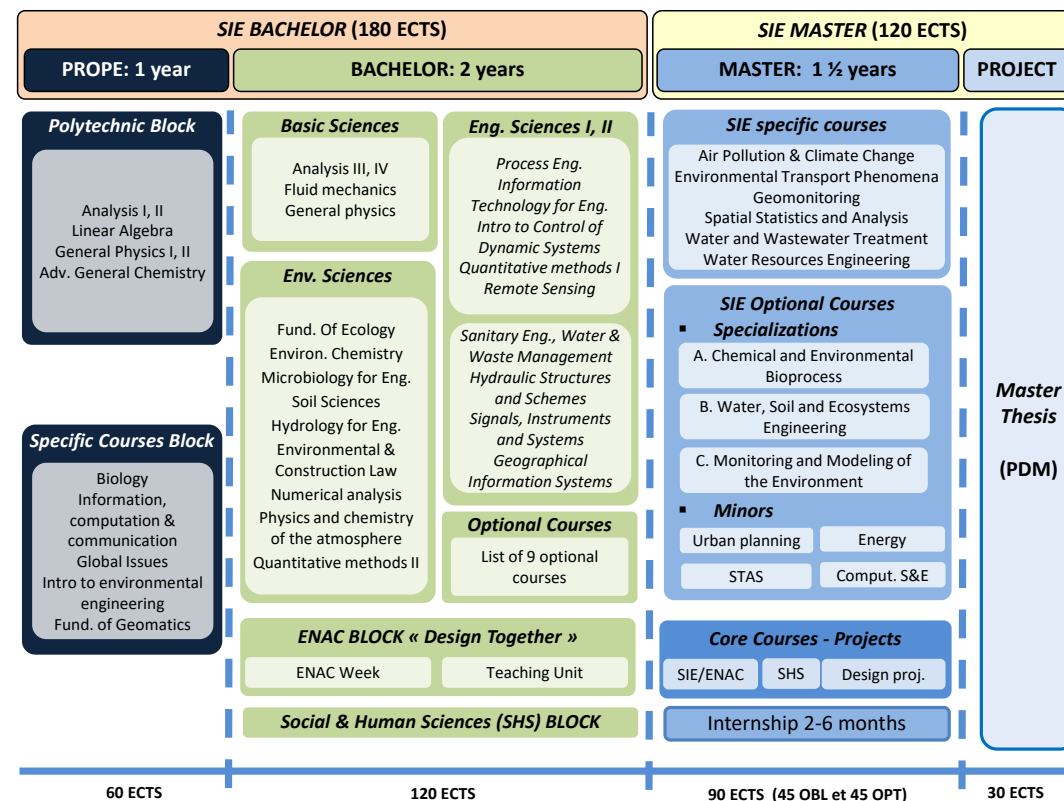


Figure 4.8. General scheme of the Bachelor-Master of Environmental Sciences and Engineering curriculum.

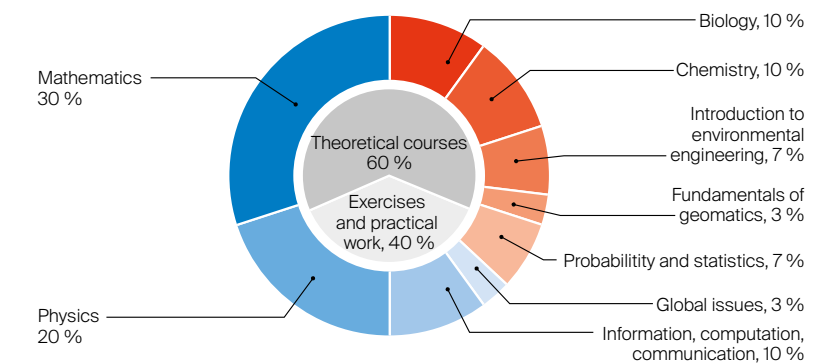


Figure 4.9. Overview of the SIE study plan, propaedeutic year.

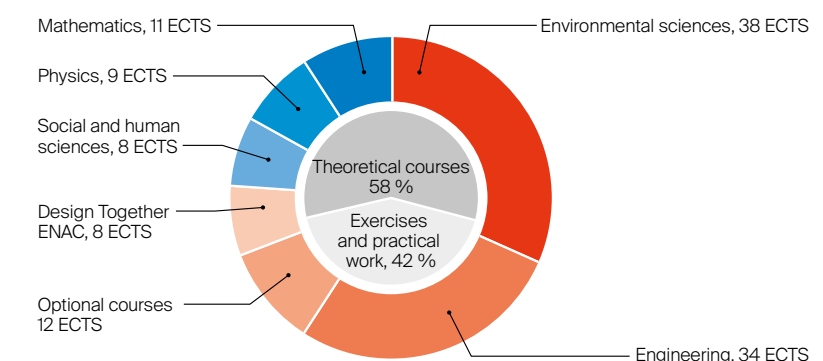


Figure 4.10. Overview of the SIE study plan, Bachelor level.

The current program is presented in Figure 4.8 with the Bachelor and the Master cycles. The most important components are:

- [Propaedeutic year](#), mostly dedicated to basic sciences (mathematics, physics, chemistry, biology, computer science)
- [Two-year Bachelor](#), mostly dedicated to fundamental environmental and engineering sciences, with several options offered during the third year to prepare for the Master's specializations
- [Two-year Master](#), which includes 90 ECTS of courses, completed by an [internship](#) in industry and a [Master project](#) of 30 ECTS (1 semester)

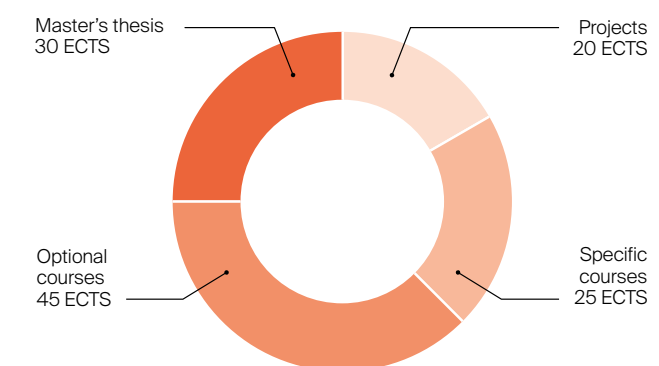


Figure 4.11. Overview of SIE study plan, Master level.

At the Master level, 5 core courses (among 6 that are offered) ensure a solid common ground to all SIE students. Other optional courses can be grouped by the students within the three specializations (to deepen their competences) or selected as interdisciplinary Minors (offered by other programs) to broaden their competence areas.

Specializations of the SIE program

- Chemical and Environmental Bioprocesses
- Water, Soil and Ecosystems Engineering
- Monitoring and Modeling of the Environment

Minors recommended to SSIE students (with the program in charge):

- Urban Planning (ENAC)
- Energy (Mechanical Engineering)
- Science, Technology and Area Studies (STAS) (College of Humanities)
- Computational Sciences and Engineering (Mathematics)

Enrolment

The Bachelor program welcomed increasing numbers of new students since its creation in 2003-2004, with a peak of 87 new students in 2012 (Figure 4.23). There was a drop in new students in 2013 and 2014. A reinforced effort in the promotion of the program, mainly in high schools in all regions of Switzerland, seems to have been successful.

At the Master level, there are around 50 graduating students each year (Figure 4.24). There is presently a slight decrease in the overall number of registered students that can be explained by the propagation of the registration drop of 2013-2015. Welcoming more outstanding external candidates to the Master program (Figure 4.25) is a goal of the Section. This will be systematically addressed in the forthcoming years.

From a gender balance perspective, the proportion of female students is in the range of 30-50% every year. This relatively high proportion could be related to the high societal importance of environmental issues within the broad spectrum of engineering activities offered at EPFL.

4.2.4.3 Quality of the Program

Each semester, all SIE courses are evaluated by students. In Figure 4.12, the evaluation of all Bachelor and Master courses over the last 4 years is classified according to the negative response rate. It shows that the large part of SSIE courses are very positively rated.

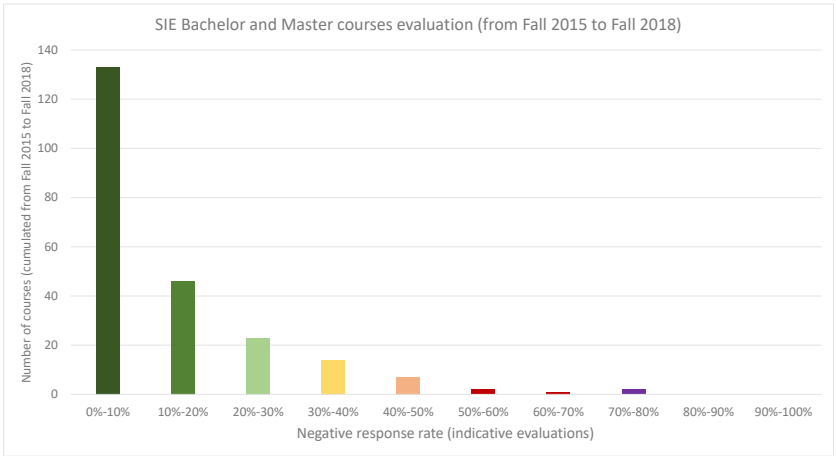


Figure 4.12. Cumulative results (fall 2015 to fall 2018) of the indicative evaluation for all Bachelor and Master Courses offered by the Environmental Sciences and Engineering section.

Committees

The curriculum is under constant scrutiny for quality insurance, under the supervision of different bodies:

- The Teaching Commission, composed of delegates of teachers and students, is the decision-making body for the curriculum.
- The Advisory Board is composed of 5-10 representatives of companies and agencies active in environmental engineering. They convey the main trends in professional activities of environmental engineers to the program management, and they review the goals and content of the program.
- The Academic Committee is composed of three senior professors of the program (with one external reviewer, currently from ETHZ). They review in turn all courses of the curriculum, considering in-depth assessments of the students, learning outcomes, course content, and exam content and results. They return their findings to the Section and to the teachers of the reviewed courses with improvement proposals.

The whole faculty (professors and MERs) convene approximately three times per semester and discusses all significant program and teaching issues.

The design of such new multidisciplinary programs still remains a challenge to universities and institutes of technology forcing the new curricula to be not only innovative but also to anticipate the needs of future areas. SSIE faces this challenge by a constant exposure to professional bodies, through our network of [Alumni](#), through the Advisory Board, and through regular contacts with other universities.

The regular accreditation of the program (most recently in 2015 and 2018) by the Swiss accreditation body (AAQ) and by the French CTI is also a guarantee of its constant adaptation to high professional requirements and academic standards.

Benchmarking

A review of the program by consideration of similar curricula of the Technical University of Denmark in Copenhagen (our partner for a Dual Master) and of ETHZ led to a general scheme of Environmental Engineering curricula (Figure 4.13). This scheme summarizes taught disciplines (that may group several courses), going from the polytechnical foundation on the left to the most specialized courses on the right. Disciplines converge into five main Study Lines (more general structure as our specializations).

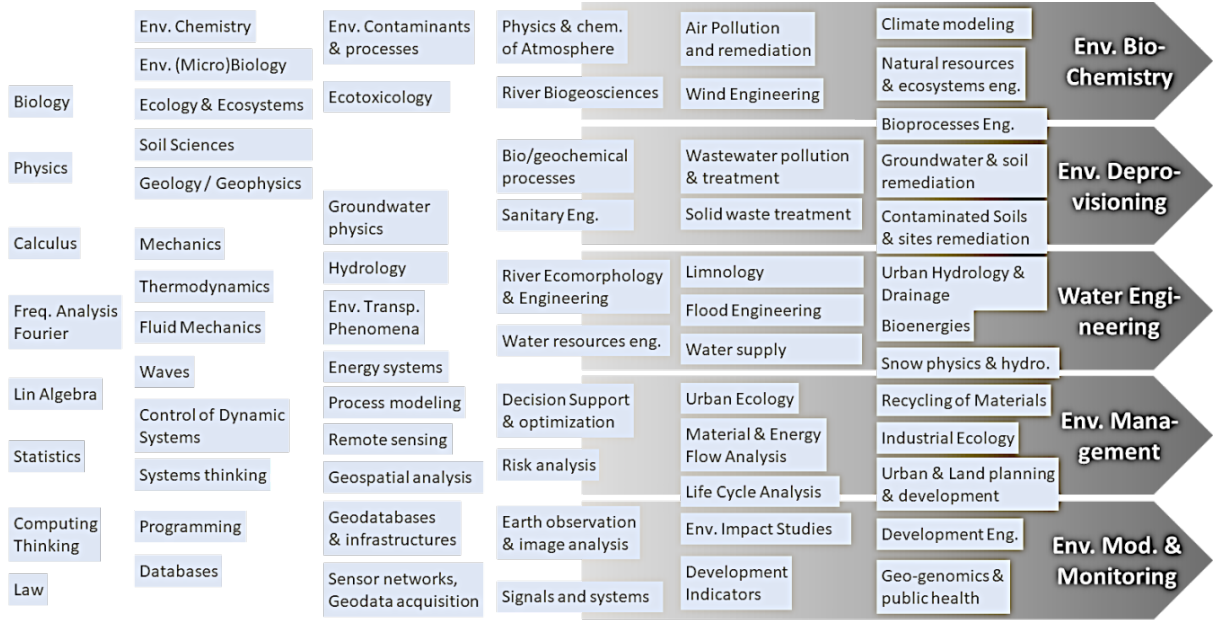


Figure 4.13. General scheme of Environmental Engineering curricula.

Moreover, another benchmark comparing the ratios of four generic classes of courses between several leading Bachelor programs in Environmental Engineering (MIT, UC Berkeley, and University of Illinois at Urbana-Champaign, Figure 4.14) shows the significant importance given in our program to fundamentals and to data science and technology.

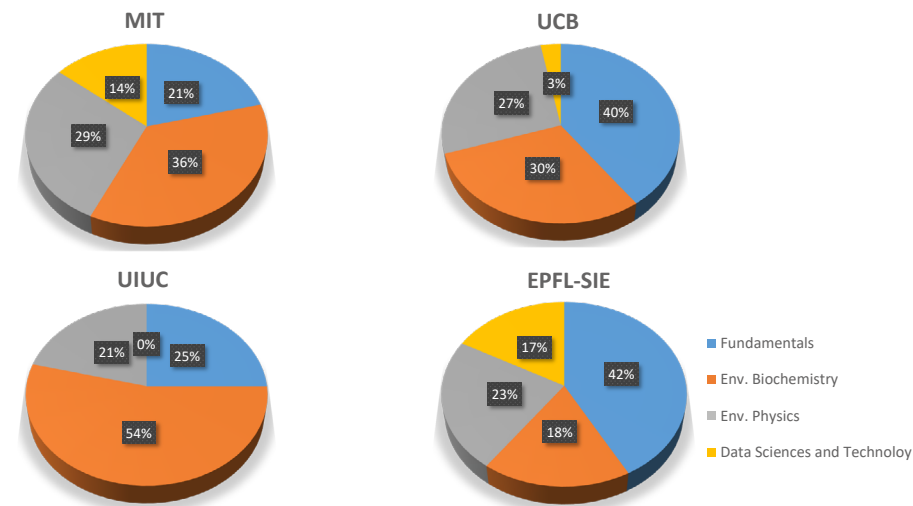


Figure 4.14. Comparison of 4 classes of courses. Massachusetts Institute of Technology (MIT), University of California, Berkeley (UCB), University of Illinois at Urbana-Champaign (UIUC).

Professional Integration and Career Satisfaction

Figure 4.28 gives recent (2018) Alumni feedback on professional integration and career satisfaction, organized by EPFL's career center. The overall satisfaction is evident. However, there is less appreciation for the adequacy of the program, for the recognition of the title, and with the salary. The results in Figure 4.15 suggest that graduates take more advantage from the working methodology learnt than from their technical competences. These results may be related to the extremely broad field of activities of environmental engineers (Figure 4.16). Our students acquire a large palette of competences that they further develop according to the requirements of their working environment.

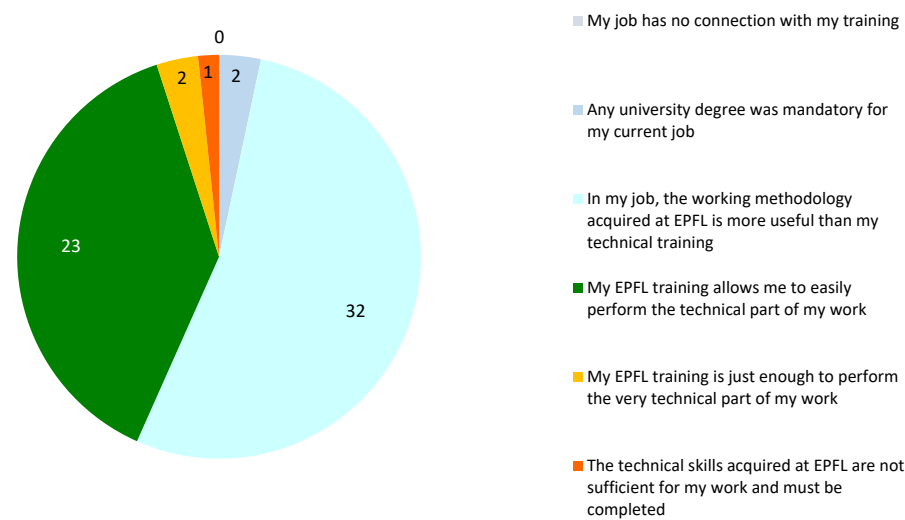


Figure 4.15. Survey of the work perception and condition (2018).

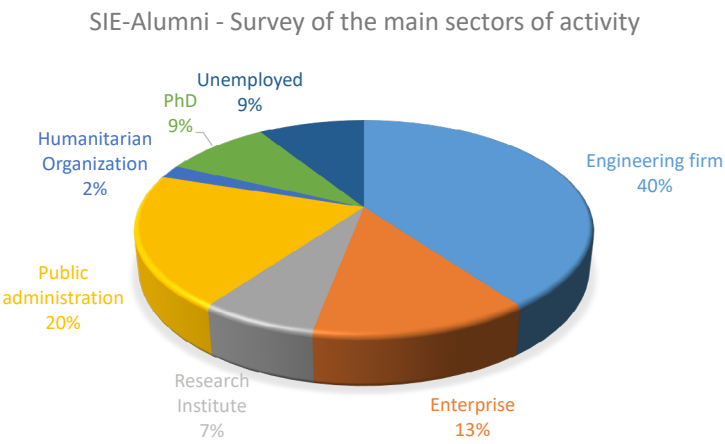


Figure 4.16. Survey of the main sectors of activity for the SIE alumni who graduated between 2006 and 2016.

The survey, managed by EPFL's Teaching Support Center, was a prototype that will be extended to all Masters from EPFL. Other useful feedbacks obtained, which have since been validated by the Advisory Board, are:

- The program matches very well the technical and professional requirements of Alumni.
- The opportunities to foster cross-disciplinary competences (e.g., languages, project management) should be strengthened.
- Links to the professional actors should be established early enough to support our students' choices for options, specializations and Minors.

4.2.4.4 Teaching Resources

The SIE curriculum relies mainly on the teaching contributions of the professors and MERs of the Institute of Environmental Engineering, complemented by EPFL professors from other Sections. External lecturers are also needed given the breadth of the professional requirements in environmental engineering. The program will face many challenges and opportunities (see below) up to 2025 due to retirements of several professors.

4.2.4.5 Anticipated Curriculum Evolution

The Section has a working group to identify long-term opportunities and challenges for environmental engineering and sciences. Activities of environmental engineers cover a variety of areas:

Global Level

- Global change (including effects and mitigation of population growth and shifts)
- Climate change (effects and mitigation of changing climate on natural resources)
- Deterioration of water, soil and air quality and associated risks to human and ecosystem health
- Energy transition
- Resource scarcity
- UN Sustainable Development Goals

Local/Regional Level

- Effect of global change at local level (e.g. alpine region) on water quantity and quality (and how to assess and mitigate it)
- Effect of land use and restoration on environmental quality (and how to assess it)
- Energy transition (resource evaluation, impacts on environment and humans)

- Effect of global change on natural hazards and anticipation of local protective actions
- Impact of extreme environmental conditions on local human activities and infrastructure
- Big data in environmental monitoring (e.g., smart cities)

The following trends have been identified for strengthening:

- Integration of small-scale knowledge with system-level processes
- Use of big (distributed) data to anticipate and assess risks and impacts
- From technological solutions to incorporation of natural and human aspects

These activities and trends will be considered for the long-term development of our Bachelor and Masters programs. The following principles and near-term changes will guide any curriculum development:

- The strength of the polytechnic foundations is a clear market advantage. We will maintain, if not strengthen, their position in the program. The introduction of a refocused propaedeutic year for the whole EPFL last Fall is in line with this vision.
- Reinforced training in computational thinking and reasoning is introduced in the first year. It will be complemented in the Bachelor program by courses in computation, algorithmic development and programming.
- Necessary bases in environmental and engineering sciences are the core of the Bachelor program.
- Essential notions for each of the 5 study lines are taught to all Master students (Core Courses). However, with the available resources and market demands, we focus on our fields of excellence in Environmental Biochemistry, Water Engineering, and Environmental Modeling and Monitoring.
- Other emerging fields relevant to our students, e.g., energy management, are available as Minors.

The [revised Bachelor program](#) will be introduced between 2019 and 2021. A major revision of our Master program is planned for the Fall of 2021.

4.2.5 Student Statistics and Alumni Survey

The following graphics show, for each Section, the:

- Evolution of Bachelor and Master student numbers
- Evolution of Bachelor and Master graduates and the proportion of female graduates
- Evolution of the number of external Master candidates
- Origin of students registered in first year bachelor (Swiss, residents, non-residents)

Architecture (AR)

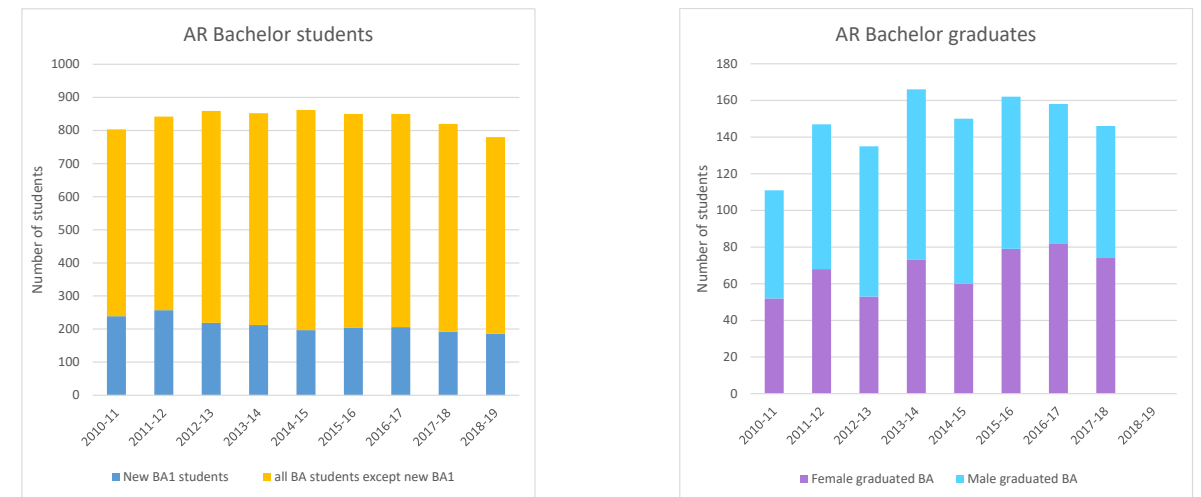


Figure 4.17. The number of architecture students at Bachelor level.

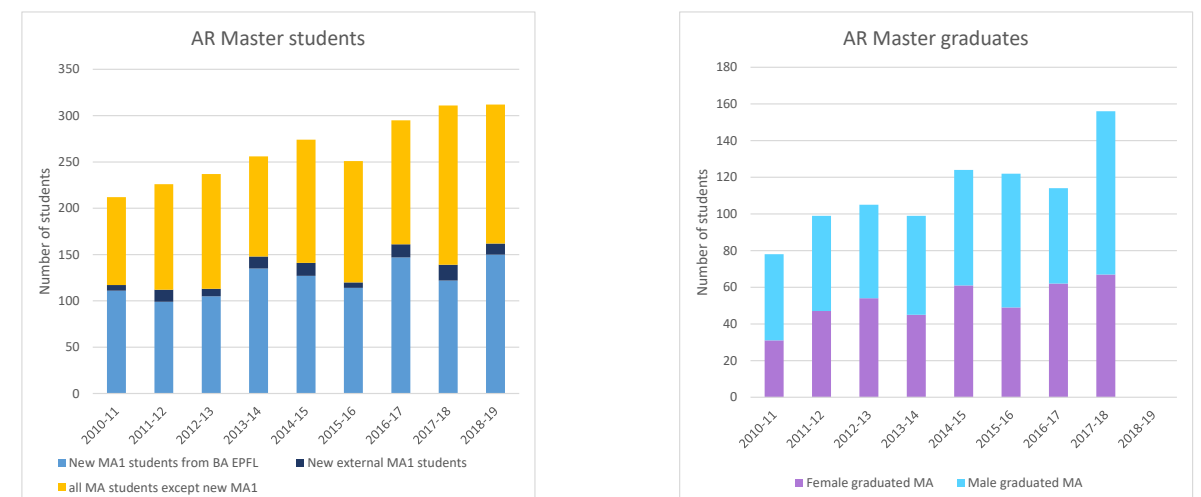


Figure 4.18. The number of architecture students at the Master level.

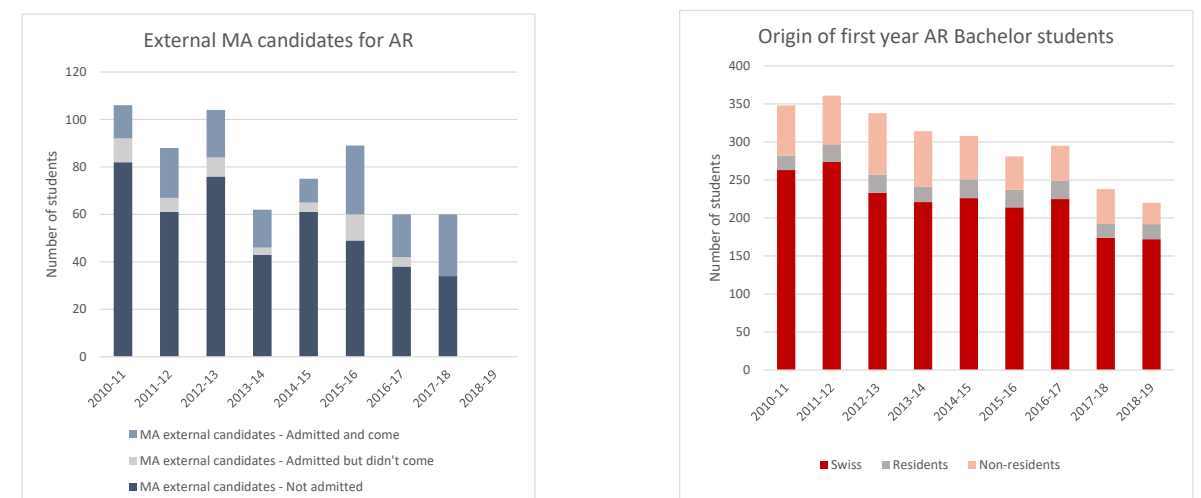


Figure 4.19. The number of external Master (MA) candidates and first year Bachelor (BA) students in architecture.

Civil Engineering (GC)

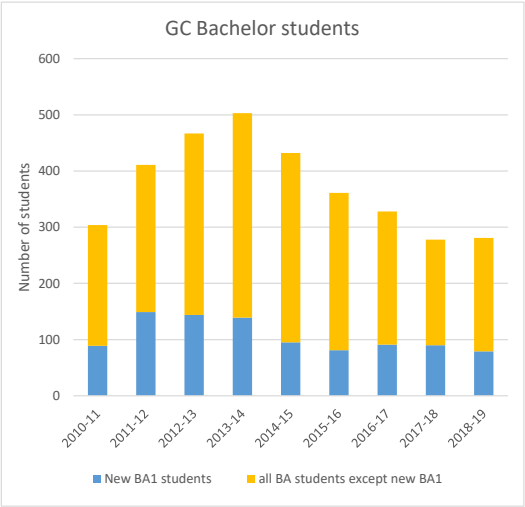


Figure 4.20. The number of civil engineering students at the Bachelor level.

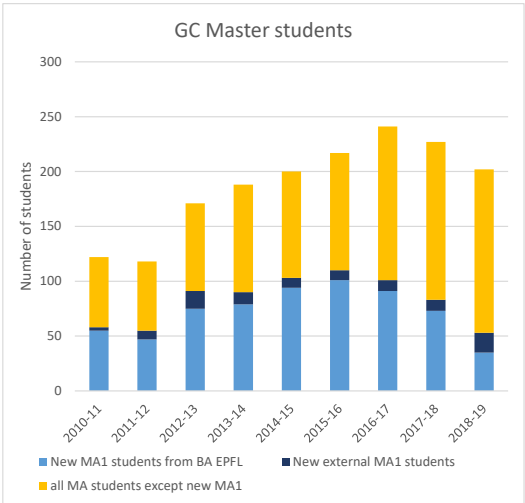


Figure 4.21. The number of civil engineering students at the Master level.

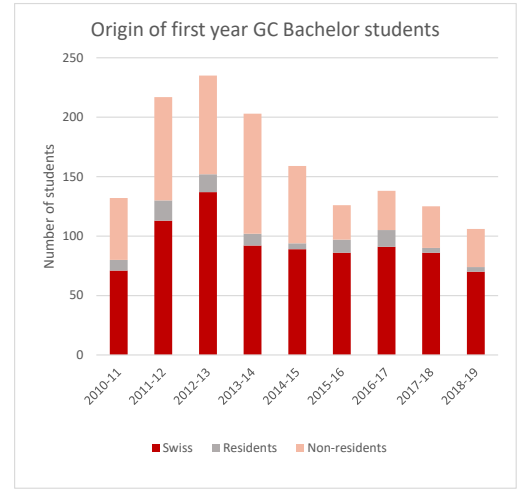
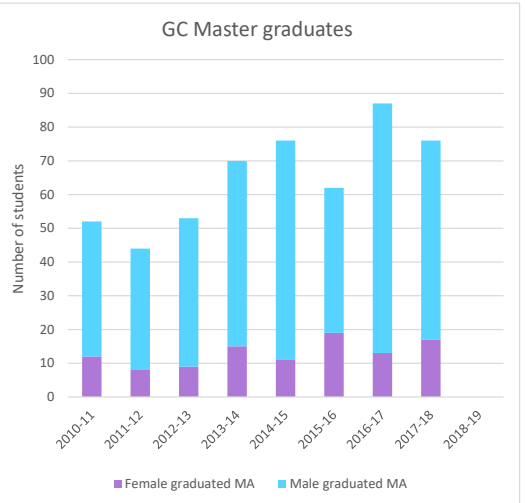
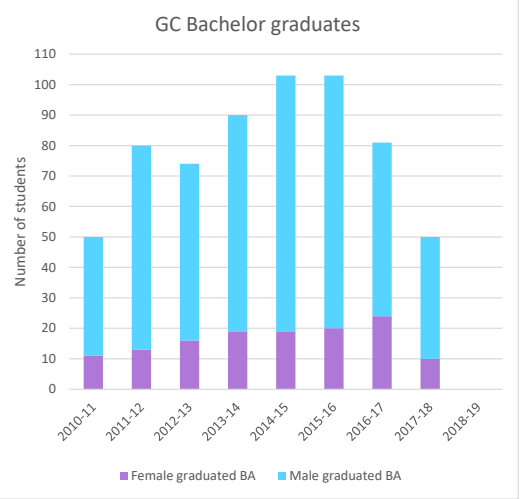
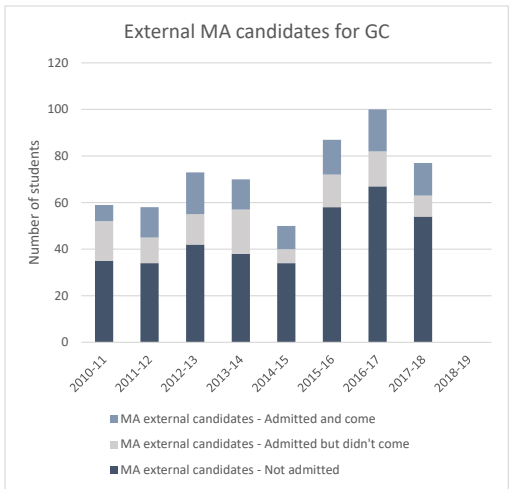


Figure 4.22. (Left) External candidates at the entrance of the Master of Civil Engineering. (Right) The origin of students registered in first year Bachelor (Swiss, residents, non-residents), including those who repeated the first year.

Environmental Sciences and Engineering (SIE)

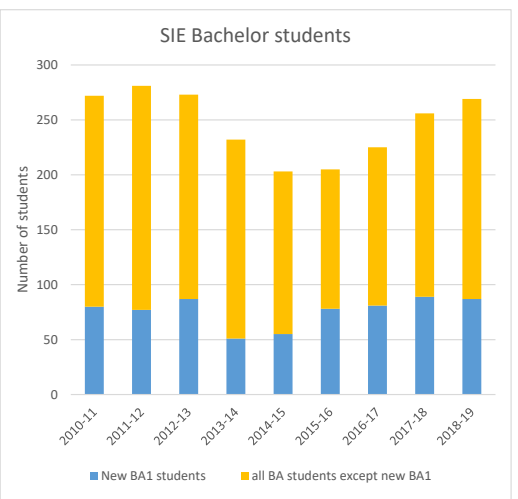


Figure 4.23. Evolution of the number of SIE Bachelor students.

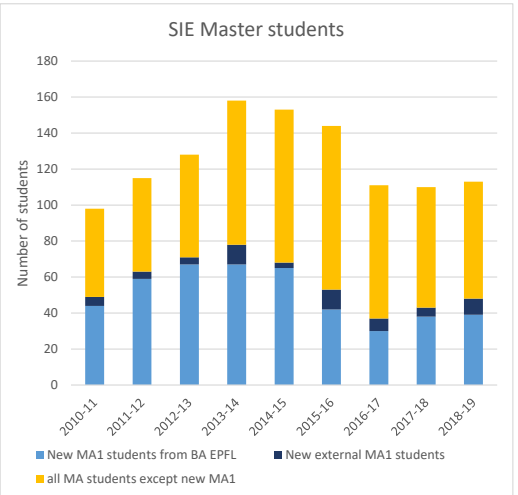


Figure 4.24. Evolution of the number of SIE Master students.

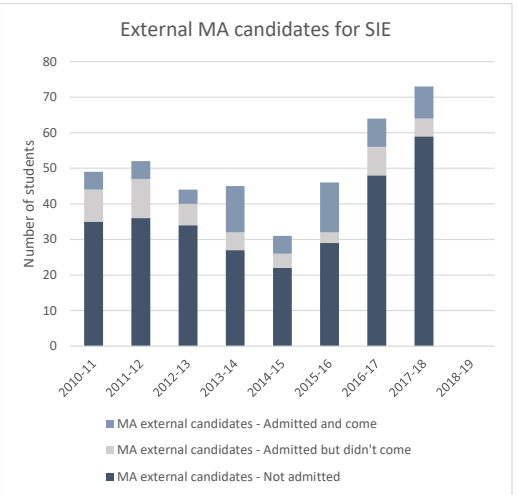
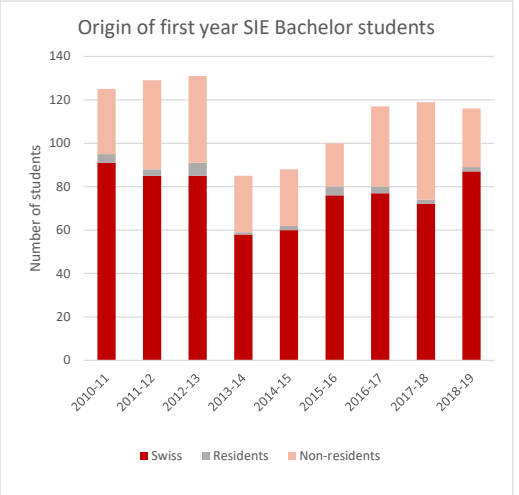
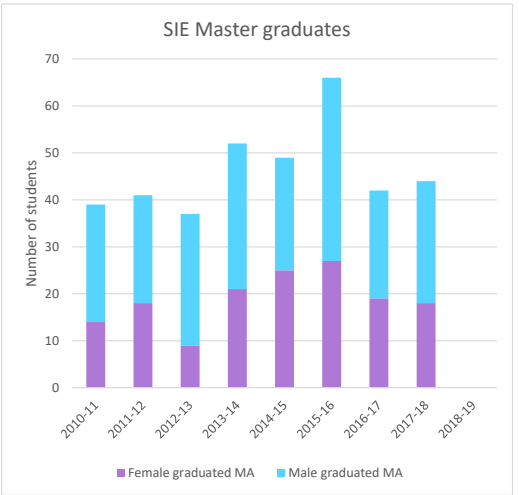
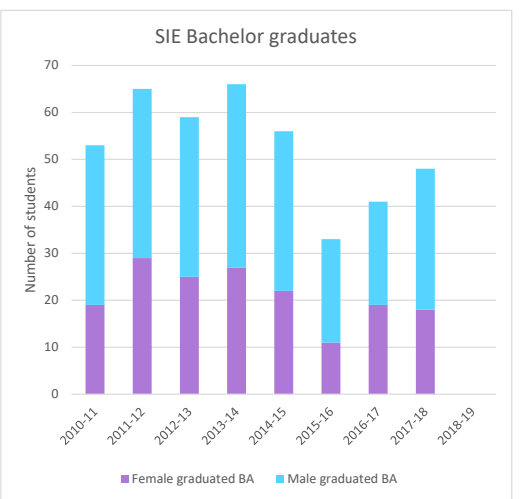


Figure 4.25. (Left) Evolution of the number of Master external candidates. (Right) Identification of the origin of first-year SIE Bachelor students.



Alumni Survey¹

Architecture (AR)

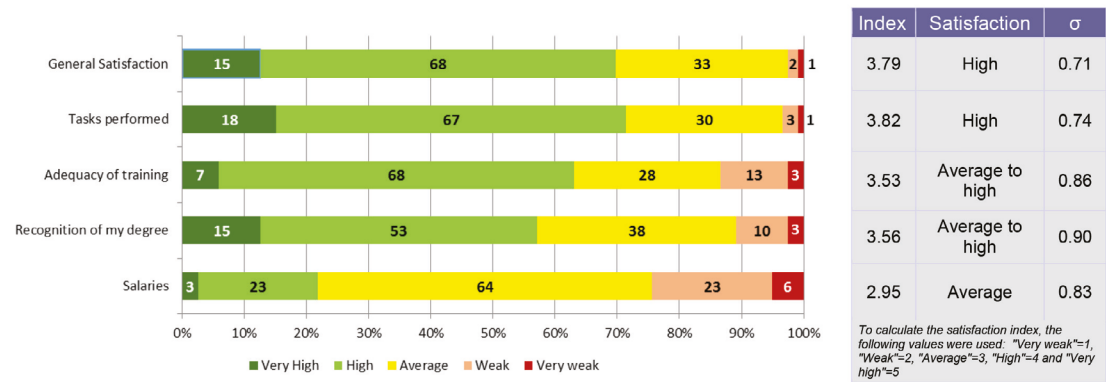


Figure 4.26. Satisfaction at work for architecture graduates after one year of employment.

Civil Engineering (GC)

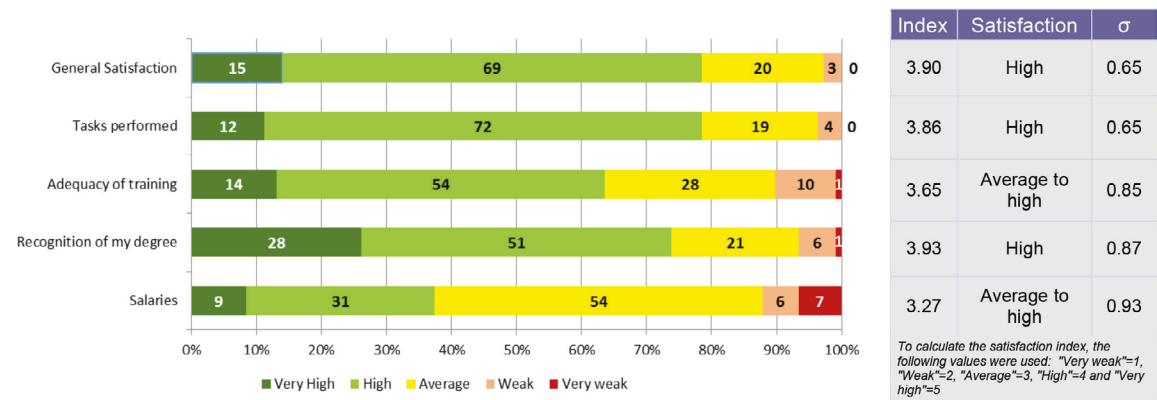


Figure 4.27. Satisfaction at work for civil engineering graduates after one year of employment.

Environmental Sciences and Engineering (SIE)

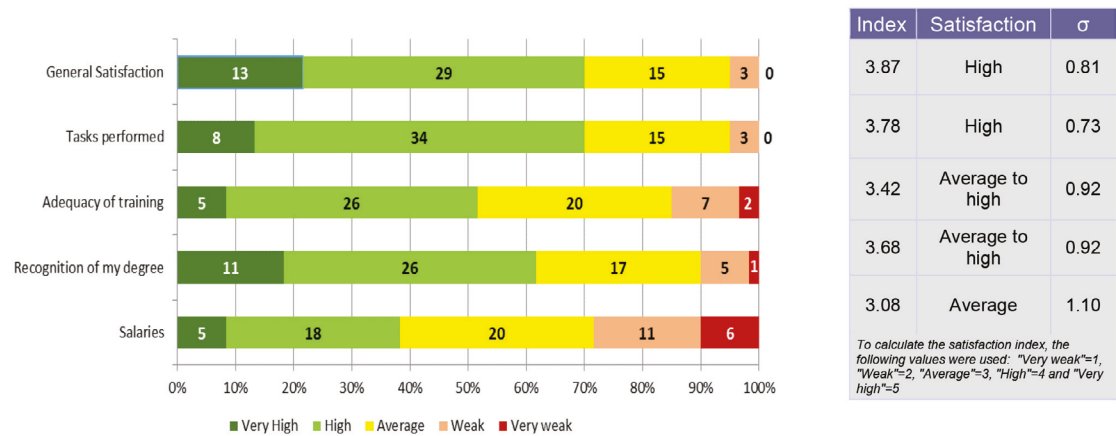


Figure 4.28. Satisfaction at work for SIE graduates after one year of employment.

¹Data: EPFL Career Center, November 2018. Graduation years from 2013 to 2016 (see Annex).

4.3 Doctoral Programs

In 2003, doctoral education at EPFL was organized under the framework of a Doctoral School (EDOC), which coordinates domain-specific doctoral programs that are responsible for management of PhDs. PhD supervisors join doctoral programs according to their research interests. Currently

21 doctoral programs are offered at EPFL. In the following, we give an overview of the general mechanisms regulating doctoral education at EPFL and then focus on four different programs in which ENAC is strongly involved.

4.3.1 Overview

While the framework offered by EDOC ensures cohesion on a number of key regulations common to all programs, the individual doctoral programs benefit of significant freedom in establishing detailed operational practices for student recruitment, course requirements, quality control checkpoints, and various scientific and outreach activities. Formal regulations at the EDOC and program levels are discussed and formulated in dedicated committees. These include the CDOCT committee composed of the program directors, representatives of the Vice Presidency for Education, and doctoral student representatives. Program committees include faculty associated with a given program as well as doctoral student representatives. One key peculiarity of the doctoral organization at EPFL is that doctoral programs are transversal to Bachelor and Master educational programs and their associated teaching Sections, resulting therefore in a matrix organization. As a consequence, while certain doctoral programs are aligned with the underlying Bachelor and Master programs (e.g., EPFL offers Bachelor, Master and Doctoral programs in Electrical Engineering), others have a more interdisciplinary signature involving faculty and students attached to multiple teaching Sections, often belonging to different faculties (e.g., the Doctoral Program in Energy). While this matrix organization might appear complex and unusual, it promotes interdisciplinary and cross-institutional educational initiatives.

end of this two-stage selection process, only the very best candidates (< 10% of the applicants) find a PhD opportunity. Doctoral studies last typically between four and five years; at the end of the first year a candidacy exam is organized (at most, two attempts are possible). The candidacy exam is a second filter. Annual reports signed by the student and the advisor(s) are evaluated by the doctoral program committee. The studies end with a private exam (only the candidate and appointed jury members, including the advisor and potentially a co-advisor, can attend) followed by, in case of successful exam, a public seminar given by the PhD student.

All PhD students are required take courses during their studies (at least 12 ECTS). Programs are allowed to enforce specific restrictions on the course choices (e.g., 4 ECTS must be taken at the doctoral level or among common core courses). In addition, they are required to engage in teaching activities as teaching assistants and/or student project supervisors. Teaching activities are coordinated by the teaching Section to which the research advisor belongs.

Each PhD student is assigned a mentor within the faculty. The mentor is not involved in the student's research project and acts as an independent advisor that helps students navigate through their doctoral studies. The mentor can also help detect and advise on potential problems. Moreover, student representatives regularly interact with the faculty members in the committee as well the administrator of the doctoral program, which also helps to identify specific problems and to find possible solutions.

Candidates interested in doctoral studies at EPFL apply to one or more doctoral programs. Note that PhD students at EPFL are engaged on employment contracts, not as scholarship holders. In most programs, the first selection of candidates is done by the program committee, giving admissibility status valid for one year. This step filters applicants on the basis of orientation and, importantly, quality. Next, PhD advisors in the program are invited to interview the selected applicants and identify potential candidates they would be ready to financially support and advise over their doctoral studies. At the

In terms of overall PhD student population, ENAC experienced a modest growth since the last audit, which is largely due to the stable population of PhD advisors in the faculty. In 2011, 269 PhD students were working at ENAC while at the end of 2018 there were 280. The average ratio of PhD students per faculty (3.7) since the last audit is steady.

Table 4.2 shows the doctoral programs in which ENAC PhD students are active, as well as the Section to which their teaching activities are associated. Around 93% of ENAC’s PhD students are found in four doctoral programs, all of which have been or are directed by ENAC professors. The four programs are:

- Doctoral Program in Civil and Environmental Engineering (EDCE)
- Doctoral Program in Architecture and Sciences of the City (EDAR)
- Doctoral Program in Mechanics (EDME)
- Doctoral Program in Robotics, Control, and Intelligent Systems (EDRS)

The Doctoral Program on Energy (EDEY) is becoming increasingly relevant for ENAC and has the same interdisciplinary flavor as EDRS. However, as for the time being no ENAC faculty has served as Director for this program, we will not cover its peculiarities in this report.

Table 4.2. PhD students at ENAC as at 1 January 2019 with their Section and Doctoral Program affiliations.

DOCTORAL PROGRAMS/SECTIONS	SAR	SGC	SSIE	TOTAL	FRACTION OF ENAC POOL
Civil and Environmental Engineering (EDCE)	18	56	80	154	55%
Architecture and Sciences of the City (EDAR)	56		4	60	21.5%
Mechanics (EDME)		33	2	35	12.5%
Robotics, Control, and Intelligent Systems (EDRS)		1	10	11	4%
Chemistry and Chemical Engineering (EDCH)			1	1	0.5%
Computer and Communication Sciences (EDIC)		1	1	2	0.5%
Electrical Engineering (EDEE)		3		3	1%
Energy (EDEY)	10	2		12	4%
Management of Technology (EDMT)			1	1	0.5%
Material Science and Engineering (EDMX)	1			1	0.5%
Total PhD students	85	96	99	280	100%

Below, we focus on the four doctoral programs for ENAC PhD students, highlighting first their main figures and commonalities, and then their specific peculiarities.

EDCE and EDAR are good examples of doctoral programs aligned with the underlying teaching organization. As can be seen from Table 4.3 (association of faculty to teaching units aggregated over schools), most of the faculty in these two programs are associated with one of the teaching Sections within ENAC (SAR, SGC or SSIE). EDME and more so EDRS are instead inter-school programs benefiting maximally from the transversal organization of the Doctoral School mentioned above.

Table 4.3. Number of PhD advisors associated with the four main doctoral programs of ENAC and the proportion of advisors from ENAC.

DOCTORAL PROGRAMS	ENAC	IC	SB	STI	SV	COLLEGES, CENTERS	TOTAL	ENAC INVOLVEMENT
EDCE	53		2	1		2	58	91%
EDAR	34					2	36	94%
EDME	11		1	22	1		35	31%
EDRS	3	3	1	23	2		32	9%

EDCE, EDAR, EDME and EDRS all follow the standard EPFL recruiting procedure. Three deadlines per year (January 15, April 30 and September 15) are centralized at the program level followed by a distributed interviewing process of the candidates shortlisted by the respective program committees, organized by one or multiple faculty associated with the program. The four programs have different restrictions on application evaluations outside these regular deadlines (fast track): EDAR does not allow it, EDRS evaluates applications outside deadlines only in case of demonstrated alternative offers from competitor institutions, EDME only in case of proven fast hiring needs, and EDCE only if the evaluation request arrives within one month of the regular deadlines.

The required course work for PhD students is 12 ECTS for EDCE, EDME and EDRS, and 14 ECTS for EDAR. Each program offers a set of relevant courses directly and recommend others in other doctoral or Master programs. Different programs restrict the course choices differently: for instance, EDCE requires its PhD students to take 4 ECTS from a restricted list of core courses, EDAR enforces 9 ECTS to be taken from mandatory courses while EDRS and EDME leave additional freedom in the choice of courses. The course palette is complemented [by courses focusing on transferable skills](#), which are offered and approved at the EDOC level. Additional training opportunities for PhD students are offered by the EPFL central library¹ and the Teaching Support Center². These latter opportunities do not deliver credits and are typically organized as short workshops. Finally, each program is entitled to approve credits for courses outside EPFL (e.g., summer and winter schools, courses at ETHZ). The program director assesses case-by-case the effort invested by the student and the format used to verify the acquisition of the learning outcomes (e.g., final exam, report and presentation

of a course project) in order to validate a corresponding number of credits.

Multiple recognitions for outstanding doctoral dissertations exist at EPFL and are typically awarded annually. In addition to the best EPFL PhD thesis (very selective, one thesis of about 400 per year) and targeted engineering awards (e.g., ABB, Chorafas, Ville de Lausanne; only about 2% of the theses produced at EPFL receive such an award), a new form of recognition, the Doctoral Program Thesis Distinction, was introduced in 2017. For this latter recognition, each individual doctoral program is entitled to distribute the award to its 8% best theses of the year – the 8% figure was selected to match that for ETHZ’s Field Medals). Finally, EPFL PhD students can also apply for international awards. Some selected highlights of received prizes and available recognitions for our four programs are mentioned in their dedicated program subsections below.

All the four programs strive at balancing genders in their PhD student population. Table 4.4 shows the absolute number and the fraction of female PhD students per doctoral program and per teaching section. What this table tells us is that laboratories associated with both SAR and SSIE currently attract the highest number of female PhD students reaching essentially an almost perfect gender balance (52% and 48%, respectively) while laboratories associated with SGC (18%) still have to adopt additional promotion strategies to attract female doctoral students. EDAR as a program is well balanced (58%) while EDCE, EDME, and EDRS can improve (36%, 23%, and 27%, respectively). Thanks primarily to the laboratories associated with both SAR and SSIE, the overall ratio of women undergoing PhDs in ENAC (39%) is above the EPFL average (30%).

Table 4.4. Number and fraction of female PhD students per doctoral program and per section at 1 January 2019.

DOCTORAL PROGRAMS/SECTIONS	SAR	SGC	SSIE	TOTAL PROGRAM
EDCE	7 (39%)	10 (18%)	39 (49%)	56 (36%)
EDAR	32 (57%)		3 (75%)	35 (58%)
EDME		7 (21%)	1 (50%)	8 (23%)
EDRS			3 (30%)	3 (27%)
Other programs	5 (45%)		2 (67%)	7 (35%)
Total female PhD students	44 (52%)	17 (18%)	48 (48%)	109 (39%)

¹ <https://library.epfl.ch/en/training-en/training-by-public-en/training-phd-en/>

² <https://cape.epfl.ch/workshops-and-courses-for-doctoral-assistants>

According to the EPFL career center reports¹, roughly 40% of EPFL PhD graduates end up in academia and research centers while 60% go to industry. It is therefore important that the EPFL doctoral education fulfill the expectations of both the academic and industrial sectors. ENAC graduates associated to the three engineering programs (EDCE, EDME and EDRS) follow the same trend (e.g., 43% of the graduates having obtained their degree between 2013 and 2016 went to academia and research centers) while for EDAR the proportion of researchers is even slightly higher (e.g., 50% for the graduation years 2013-2016). According to the surveys regularly carried out by the EPFL career center, ENAC PhD students experience a high satisfaction at work after their departure from EPFL, consider high the appropriateness of their doctoral education as well as the general recognition of their PhD title.

4.3.2 Civil and Environmental Engineering (EDCE)

Defining Features

The goal of EDCE is to train scientists and engineers who will foster a vibrant and productive society while ensuring environmental sustainability. A defining feature of EDCE is the high diversity in the educational backgrounds of our students. While many EDCE students hold a degree in civil or environmental engineering, numerous others have backgrounds in mathematics, natural sciences or other engineering disciplines. To accommodate this diversity, students are encouraged to follow both subject-specific and general engineering courses to help them obtain the knowledge needed for their PhD projects. Most importantly, EDCE strives to ensure that each student possesses the necessary quantitative skills to perform a PhD in engineering. Independent of their background, each EDCE student must therefore pass a rigorous, quantitative doctoral course within the first year of their PhD. This course can be chosen among a block of six courses in statistics, programming or engineering foundations.

Achievements since 2011

- **Student Activities** – EDCE has a very active group of student representatives, who greatly enhance the social and academic experience of EDCE students during their time at EPFL. The student representatives actively participate in EPFL politics, and organize a range of social gatherings, including happy hours, sporting events (e.g., ski trips or volleyball tournaments), new student welcome events, movie nights, and the SeminApéro. This latter event provides a forum for EDCE students to briefly and informally present their research activities to their peers, followed by discussion over pizza and beer. EDCE students are also among the PhD student representatives and delegates of the newly formed, EPFL-wide student association (PolyDoc).
- **Mobility Award and EDCE Thesis Distinction** – In 2011, EDCE instigated its mobility award, which provides financial support to students wishing to conduct research over a brief period at an institution abroad. The mobility award has two annual deadlines, and up to CHF5k can be requested per award. The EDCE Thesis Distinction was awarded for the first time in 2018 to Drs. Luca Carraro (ECHO) and Davide Wüthrich (LCH).

Future Plans

Over the next years, EDCE has identified two priorities:

- **Promoting Female Doctoral Students** – EDCE boasts one of the highest percentages of female students at EPFL (see Table 4.4). Nevertheless, more can and should be done to better guide female students through the PhD process and encourage their academic or professional careers. The EDCE commission has aims to implement actions specific to female students (e.g., meetings with notable alumnae). In addition, we will actively encourage our students' participation in workshops organized by EPFL or the ETH domain aimed at developing the career paths of female scientists and engineers.
- **Integration of External Students** – The already significant fraction of external (i.e., not on the Lausanne campus) students affiliated with EDCE will further increase with the establishment of ALPOLE (Valais satellite campus, Sion) and the projected growth of the Smart Living lab (Fribourg satellite campus). External EDCE students often travel to EPFL for teaching, coursework and exams, but are otherwise quite disconnected from the EDCE community. A goal for the coming years is bring these external students closer to the EDCE fold.

¹ <https://carriere.epfl.ch/telechargements/>

4.3.3 Architecture and Sciences of the City (EDAR)

Defining Features

EDAR brings together in one doctoral program the world of architecture and that of social sciences concerned with inhabited space and combines basic and applied research in an interdisciplinary perspective. Its scientific orientations encompass four research areas:

- History and theory
- Integrated design and sustainability
- Complex design
- Sciences of the city

EDAR is based on two fundamental principles: the strong relationship between basic and applied research, and interdisciplinarity. First, the link between theory and practice enables students to treat the project – regardless of its subject (architecture, urbanism, spatial development) and its actors (from individual residents to the local community as a whole) – both as an object of study and as a research challenge. Second, interdisciplinarity as conceived of in the EDAR program is multidimensional. It is situated inside architecture (history, theory, projects) and in urban sciences (geography, urban sociology, environmental economics, housing and networking, urbanism and spatial planning, civil engineering), and also between the two fields in that it is based on the role of a mediator between the problems of the city, of mobility, of space, and of inhabiting it.

Achievements since 2011

- **Course Offering** – The EDAR course catalog was fully revised. All courses are now in block format, constructed so that they address specific topics in connection with the theses of PhD students. Thus, the course catalog is evolving from year to year. This transformation has resulted in a significant improvement in course evaluations by students.
- **Scientific Exchange and Student Association** – The scientific exchange between the doctoral students and faculty associated to the program has been boosted by the annual EDAR Meetings event introduced in 2016, a day of presentation and discussion of theses in progress within the framework of the program. The EDAR committee has also dedicated attention to supporting the student association of the program. In recent years, EDAR PhD students have been very active. In particular, they assumed a proactive role in improving and creating various initiatives that enabled academic and social exchange within and beyond EPFL.
- **Newsletter** – EDAR introduced a newsletter in 2016. It is a tool for faculty and PhD students that allows for a better access to information relevant to research and academic life. The newsletter is popular, with high reading rates (up to 70% of program participants). The main themes of the newsletter are: (i) calls for proposals (papers, funding, scholarships, etc.), (ii) scientific events (colloquiums, conferences, Summer schools, meetings between PhD students, etc.), and (iii) information in relation to the doctoral program and the academic life of participants.
- **Alumni Tracking** – A large fraction of EDAR alumni end up in academic institutions. According to the most recent survey (2018), 43% are active in the academic sector, 48% in other professions, while 9% are active in both spheres.
- **PhD Thesis Prizes and EDAR Thesis Distinction** – In 2016, the Best EPFL Thesis Award was won by an EDAR doctoral student, Dr. Giulia Marino ([TSAM](#), ENAC, Figure 4.29). EDAR introduced its Thesis Distinction in 2017: the recipients were Drs. Ana Povoas ([CHÔROS](#), ENAC) and Michael Doyle ([LEURE](#), ENAC). In 2018 the EDAR Thesis Distinction went to Dr. Sonia Curnier ([LTH2](#), ENAC).

Future Plans

Over the coming years, EDAR will pursue policies already initiated in the previous period, with the following priorities:

- *Excellence* – EDAR wishes to pursue its policy of excellence, which is already leading to a very high rate of doctoral students pursuing an academic path.
- *International Visibility* – EDAR aims at increasing its international visibility through a targeted international communication policy.
- *International Collaboration* – EDAR intends to establish exchanges with other doctoral programs abroad, in particular with the Tongji University of Shanghai, the Politecnico of Turin, and the National School of Roads and Bridges (projects under development). EDAR intends also to support and promote further PhD student exchanges.
- *Alumni Community* – EDAR would like to promote an alumni community, especially for those doctoral students pursuing an academic career.

4.3.4 Mechanics (EDME)

Defining Features

The goal of EDME is to train highly knowledgeable and innovative research scientists in the field of continuum mechanics. As mechanics problems are found across the entire scope of industries and fields of application, research within EDME spans the full range of relevant themes, including environmental fluid dynamics, geomechanics, nano- and micro-mechanics, energy harvesting, soft materials, biomechanics, composites, and fracture. Studies include innovative experiments, new theories, and advanced simulation methods, often in combination and including multiscale and micro-macro scale bridging. EDME has four orientations, corresponding to the subdomains of fluid mechanics, solid mechanics, geomechanics and biomechanics.

Achievements since 2011

- *Program Growth* – The number of students in the program increased by 20%.
- *EDME Best PhD Thesis Award* – This award was established in 2013. Dr. Outi Supponen ([LMH](#), STI) was the recipient of the 2018 Best EDME PhD Award (Figure 4.29).
- *Scientific Exchange and Student Association* – In recent years, EDME has made an effort to increase the number of events and activities aiming to bring together the EPFL Mechanics community. EDME organizes the EPFL Mechanics Day, an annual meeting that includes laboratory visits and talks by invited world renowned scientists, new faculty members as well as the recipient of the EDME Best PhD thesis Award. Since 2013, PhD students also organize regular EDME PhD Symposia, which are held every three months. Master students are also invited to those symposia, in an effort to increase their interaction with PhD students and give them a chance to learn about and get involved with the exciting research being conducted at EDME.

Future Plans

Over the next years, EDME has identified the following priorities:

- *Improving Gender Balance* – EDME aims to increase the percentage of female doctoral students in the program, which is currently low. The management team is actively involved in increasing awareness of the issue within the program and looking for initiatives to attract outstanding female candidates.
- *Course Offering* – An effort is currently underway to increase the number of doctoral courses listed in the EDME course book. This will provide students with a wider range of options to satisfy their training needs.
- *EDME Thesis Distinction* – As mentioned above, in 2013 EDME already introduced a roughly equivalent recognition to the doctoral program distinction, the Best EDME PhD Award. EDME is therefore currently considering a merging of its current award with the newly available Doctoral Program Thesis Distinction.

4.3.5 Robotics, Control, and Intelligent Systems (EDRS)

Defining Features

EDRS provides students with the education necessary to be leaders in multidisciplinary areas at the intersection of computer science, electrical engineering, and mechanical engineering. It focuses on innovative methodologies to design, model, and control complex cyber-physical systems finding application in a large variety of domains, including those investigated at ENAC for the built and natural environment, mobility, and energy. The laboratories involved in the program are concerned with substantially different topics providing contributions from software (e.g., control, estimation, localization, navigation, artificial intelligence and machine learning) to hardware (e.g., mechatronics, soft robotics) but they all share the same excitement for system-level approaches and drive towards real-world applications, two key aspects that resonate well with ENAC's spirit.

Achievements since 2011

- *Program Relabeling, Identity Building, and Expansion* – In 2011 the program was called the Doctoral Program in Manufacturing and Robotics (EDPR), recalling the very successful deployment of robotic manipulators for the automation of manufacturing plants in the eighties. Multiple professors belonging to EDPR also played an important role in this manufacturing revolution. However, the research focus of the robotics community has since shifted to a number of other application domains such as planetary and ocean exploration, edutainment, transportation, health, and so on. On the other hand, research in manufacturing techniques also expanded its horizon far beyond automation (e.g., material sciences, additive and subtractive 3D manufacturing technologies). EPFL therefore supported the relabeling of EDPR into EDRS and the creation of a new Doctoral Program in Advanced Manufacturing (EDAM). EDRS and EDAM both began on 1 January 2016. The transformation from EDPR into EDRS had major positive consequences on the program. First, for its members, it substantially triggered the feeling of finally belonging to an interdisciplinary but well focused community. Second, the doctoral program shifted from an almost exclusively STI anchoring to one spanning across Faculties (while in 2011 roughly 90% of the faculty were in STI, the current breakdown, showcased in Table 4.3, indicates a more balanced distribution, with other schools participating at the level of 30%). Third, the number of applicants expanded by a factor 2.5 between 2011 and 2018 without any extra promotion activity. Fourth, the actual number of PhD students enrolled in the program also increased (15%) in the same period.

- **Gender Balance** – The EDRS committee has been continuously paying attention to the gender balance issue, perhaps because the problem is particularly exacerbated in the engineering areas that the program addresses. In particular, it screens with additional attention applications of females. It raised awareness of associate faculty of the usually fewer but brilliant female candidates. Moreover, perhaps less intuitively, the program relabeling mentioned above turned out to have an additional positive effect on the attractiveness of the program for female candidates. Notably, the proportion of female PhD students in the program went from roughly 15% in 2011 to 25% in 2018 (and even slightly higher if only considering ENAC-affiliated students in EDRS, Table 4.4).
- **Recruitment Mode** – As of 2012, the EDRS program committee has substantially influenced the recruiting mode of the associated faculty from one based essentially on individual networking to one fully leveraging the pre-screening effort of the program. Therefore, while in 2011 hired PhD students were mainly candidates who had previous interactions with associated faculty, in 2018 recruited PhD students came from applicants who interacted with faculty only as the second step.
- **Progress Monitoring** – Over the years, the EDRS program committee has raised the level of progress monitoring for doctoral studies by changing the annual report format and introducing a tighter closed-loop interaction between the program committee (evaluating all the annual reports) on the one hand, and associated faculty and PhD students on the other. This process has often allowed the program to resolve early on potential conflicts between given student-advisor pairs.
- **Events and Student Association** – As of end of 2015, EDRS has introduced a regular end-of-the-year social event where the program director informs the program community about the progress of the year. This event is popular among students and faculty and has improved the sense of community. The EDRS Student Association has in turn proactively multiplied its initiatives (e.g., social network visibility, welcoming events for new students, summer barbecue events) and a regular participation of student representatives in program committee meetings (non-confidential parts) was established.
- **PhD Thesis Prizes and EDRS Thesis Distinction** – One of the EDRS PhD students, Dr. Frank Bonnet (LSRO, STI, Figure 4.29), was awarded the 2018 Georges Giralt PhD Award, a prestigious European prize for PhD theses. As of 2018, EDRS has introduced its thesis distinction prize, based on nominations by the corresponding PhD thesis juries and a dedicated distinction committee having faculty representatives from the three main areas of the program (robotics, control, and intelligent systems). The 2018 EDRS Thesis Distinction went to Dr. Bahar Haghighat (DISAL, ENAC), who also ranked third in the MT180 EPFL competition (Figure 4.29).

Future Plans

In addition to continuing the gender balance efforts and possibly extending the course offer, over the next years, EDRS has identified the following priorities:

- **Restructuring of the Mentoring System** – Each student is assigned a mentor within the program associated faculty. However, the contact between the mentor and the student is happening more on a sporadic than regular basis, resulting in a low effectiveness of this solution in case of problems between students and advisors. A tighter coupling between the mentoring network and the program committee, regularly monitoring the student progress through the annual reports, appears necessary and also strongly supported by the Student Association.
- **Introduction of an EDRS Research Day** – A concrete draft of an annual EDRS Research Day has been discussed over the last year. The day would not only promote scientific exchanges among the laboratories associated with the program but also feature external keynote speakers (worldwide renowned researchers and EDRS alumni, both from academia and industry).
- **Alumni Database** – EDRS has started an effort to gather systematically alumni data and establish proper networking between alumni and the program, also in view of the regular organization of the EDRS Research Day. The feedback of such a network will be also instrumental to continue to improve the program over the years and at the same time fulfill expectations of both the academic and industrial worlds.



Figure 4.29. Four examples of brilliant students awarded in one of the four doctoral programs (from upper left to bottom right) Dr. Giulia Marino (EDAR, EPFL Best PhD Thesis Award, 2016); Dr. Outi Supponen (EDME PhD Award, 2018); Dr. Frank Bonnet (EDRS, George Giralt PhD Award, 2018); Dr. Bahar Haghighat (EDRS Thesis Distinction, 2018).

4.4 Interdisciplinary Education and Teaching Innovation

Interdisciplinary education in ENAC occurs at all levels, from the Design Together program to interdisciplinary Minors. Indeed, a fundamental tenet of ENAC's teaching programs is to prepare students for professional careers that are expected to involve diverse pathways that will often confront challenging, complex questions within interdisciplinary settings. In this context, it is necessary to educate students to make connections between ideas, theories, techniques and concepts across different disciplinary boundaries. A parti-

cular goal is for students to cooperatively and synergistically apply discipline knowledge across boundaries, a process that deepens understanding in cross-disciplinary settings. In such settings, and coupled with a teamwork structure, students are motivated to ask questions, and to explore novel (to them) analysis and solution approaches. Students thereby develop new knowledge and tools to become active, creative problem solvers based on understanding and application of knowledge in unfamiliar circumstances.

4.4.1 Design Together Program

4.4.1.1 Vision

As the core element of ENAC's education, the interdisciplinary teaching program Design Together is designed to enable the next generation of engineers and architects to integrate disciplinary knowledge to tackle complex challenges in a changing world.

Working together in multidisciplinary project teams, students from environmental sciences and engineering, architecture, and civil engineering acquire the abilities to design innovative solutions for a more sustainable future and become aware of their social and ecological responsibilities.

4.4.1.2 History

Design Together was conceived in 2004 to reinforce the interdisciplinary culture and spirit of the then newly created ENAC School. Whereas in the beginning it focused on the built environment, it now addresses complex issues of sustainability. It has also created and fostered interdisciplinary research and is seen as an opportunity to test and develop new teaching formats and to start interdisciplinary collabora-

tions. In 2016, an in-depth analysis of the program was performed, including detailed interviews with the next directorate, teaching staff and a student survey. Based on these results, in 2017 the program was further consolidated and program level offers on interdisciplinarity were proposed. In spring 2019 these offers are starting to be implemented.

4.4.1.3 Program Structure

Design Together is designed around four pedagogical principles:

- **Team Teaching** – Multidisciplinary teaching teams offer the courses
- **Problem-Based Learning** – Real-world problems and projects are at the heart of the courses
- **Progressive Learning Goals** – Learning goals evolve from interdisciplinarity beginner level to advanced level
- **Supporting Pedagogy** – Guided reflection on interdisciplinary challenges and tools to overcome them

The interdisciplinary program comprises different teaching formats throughout the Bachelor (compulsory) and Master (optional) cycles: [ENAC week](#) (fourth semester Bachelor), [ENAC Teaching Unit](#) (sixth semester Bachelor), and [ENAC Semester Projects](#) (first and second year Master). For each format, students choose from a wide range of topics (e.g., reuse of construction materials, construction of refugee camps, design of open areas in cities) offered by multidisciplinary teams of ENAC academics. Following a thorough analysis of the Design Together format, new plenary sessions were designed to support the interdisciplinary learning process of the students and to complement the thematic courses. These sessions are also open to ENAC students working on an interdisciplinary Master or PhD thesis project (Figure 4.30).

4.4.1.4 Learning Approach

The program develops students' interdisciplinary competences by enabling them to develop different types of intelligences (inspired by Sternberg's intelligence theory):

- **Practical Intelligence** – Collaborating, communicating, organizing, self-monitoring, self-managing, decision-making, taking leadership
- **Creative Intelligence** – Designing, problem-solving, creative and innovative thinking, risk-taking, developing an entrepreneurial spirit
- **Analytical Intelligence** – Systems thinking, breaking down a problem, critical thinking, computational thinking, analyzing quantitatively and qualitatively
- **Reflective Intelligence** – Perspective taking, reflecting on norms and values, developing self-awareness, dealing with complexity, anticipatory and adaptive thinking, developing a global mindset

These four intelligences are progressively developed from beginner-level (ENAC week) to medium-level (ENAC Teaching Unit) towards advanced-level (ENAC Semester Projects):

- **ENAC Week** – Here, the focus is on experiencing interdisciplinarity through solving a real world problem requiring the contributions of more than one discipline. An emphasis is put on creativity and practical collaborative work. The reflection on what interdisciplinarity is or what it implies is low. Students construct interdisciplinary bridges by collaborating and exchanging on a common practical project.
- **ENAC Teaching Unit** – The focus remains on creative and practical intelligence whereas reflectivity and analytical aspects are increased. Students reinforce interdisciplinary bridges by integrating disciplinary knowledge.
- **ENAC Semester Project** – Students not only perform an interdisciplinary project, but also are equipped with the tools to design an interdisciplinary project themselves. Student use the interdisciplinary bridges by conducting autonomously an interdisciplinary research project.

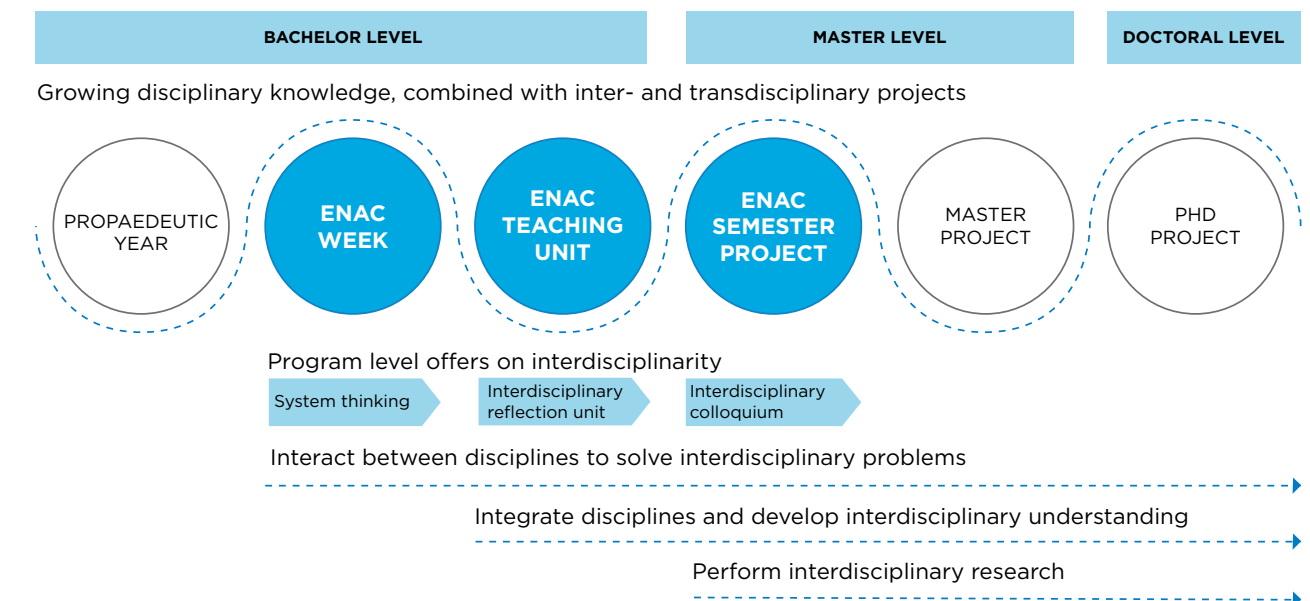


Figure 4.30. Overview over the Design Together program.

4.4.1.5 Program Level Offers

To further support the development of the interdisciplinary skills and the reflective intelligence of students, the following supporting units are provided:

- *Supporting Unit to the ENAC week* – Systems thinking course, comprised of a short introduction into systems science as a tool for interdisciplinary communication
- *Supporting Unit to the ENAC Teaching Unit* – Interdisciplinary reflection unit in which students reflect on the interdisciplinary benefits and challenges of their Teaching Unit project, as well as on the strengths and weaknesses of their specific disciplines
- *Supporting Unit to ENAC Semester Projects* – An interdisciplinary colloquium consisting of an optional seminar during the interdisciplinary project, which provides peer-to-peer exchange on how to deal with the challenges of interdisciplinary project work

Table 4.5. Design Together courses.

	ENAC Week	ENAC Teaching Unit	ENAC Semester Projects
Curriculum integration	Fourth semester Bachelor	Sixth semester Bachelor	First or second year Master
Credits	4 ECTS	4 ECTS	4 ECTS
Type	Compulsory	Compulsory	Optional
Offer (2018-2019)	13 ENAC Weeks	9 Teaching units	Ca. 30 Semester projects
Average course size	25 students/ENAC week	20 students/teaching unit	2 students/semester project
Number of students (2018-2019)	283 (159 SAR, 64 SGC, 62 SSIE)	197 (102 SAR, 46 SGC, 43 SSIE)	62 (11 SAR, 48 SGC, 3 SSIE)
Number of teachers involved	49 (28 SAR, 7 SGC, 11 SSIE, 3 other)	38 (17 SAR, 10 SGC, 6 SSIE, 5 other)	34 (11 SAR, 13 SGC, 6 SSIE, 4 other)

Student Quotes

- *I realized that we are more ingenious, more skillful and more impactful together than alone* (SAR student)
- *Working with students from other sections made me understand that our way of thinking is different but also complementary* (SGC student)
- *Interdisciplinarity has opened my eyes to the complexity of the world* (SSIE student)

4.4.2 Solar Decathlon

The Solar Decathlon competition, organized by the US Department of Energy since 2002, is a university competition structured into 10 diverse contests ranging from architecture, engineering, comfort or energy balance to communications, innovation and market appeal. The challenge is for teams of students to design and build full scale and operational energy-efficient homes relying exclusively on solar energy. This worldwide competition has since 2010 been organized in Africa, China, Europe, Latin America and the Middle East, and involves more than 200 teams and 35,000 university participants around the world. Evaluated on a 1000 points scale (100 per contest), of which 4 are measured (monitoring during competition event) and 6 are judged (ad hoc jury evaluations during competition), the Solar Decathlon is a unique opportunity to gain practical experience and training for students that prepares them to join enterprises that are leading the green energy transition, to be experienced promoters of renewable energy and to raise awareness of energy efficiency.

EPFL's participation in the 2017 U.S. Solar Decathlon was made up of students from EPFL, the School of Engineering and Architecture of Fribourg (HEIA-FR), the Geneva School of Art and Design (HEAD-Genève), and the University of Fribourg (UniFR). In all, the project engaged about 250 students over its 3.5 years duration with around 150 supervisors from

the professional and academic sectors, and close to 50 sponsors. This remarkable team showcased Switzerland's capability in dealing with questions related to sustainable development in the fields of energy, environment, architecture, construction and solar technologies. The project was inherently interdisciplinary, with student involvement from programs in different branches of engineering, energy systems, architecture, communication, graphic design, and project management. For three of the four partner schools, which joined forces since 2014 under the Smart Living Lab research center in Fribourg (section 2.5.1.1), it was also an opportunity to work together on a collaborative project and develop a demonstrator of their activities.

The Swiss team's project, named Swiss Living Challenge, demonstrated how a small, 150 m² pavilion can influence local behavior to create more sustainable lifestyles and more sustainable neighborhoods. Their solar house, the NeighborHub (Figure 4.31), won the Solar Decathlon competition against ten other teams – nine American and one European – with the highest difference in scores in the history of the competition, and with eight podiums out of ten contests, with six in first place. For the participants, this unique experience was an unforgettable and educational human adventure.



Figure 4.31. Swiss Team after the victory announcement at Solar Decathlon 2017 site in Denver, Colorado.

4.4.2.1 Student Experience

Students taking part in the project were coached by academics and experts from all four participating schools and by professionals from the industry sector in a variety of fields, ranging from design or engineering aspects (energy, sustainability, urban design, computational engineering, environmental assessment, water systems, materials, etc.) to project management, fundraising, graphic design, business, marketing and communication. The project structure consisted of seven Work Packages managed by 1-2 students and 1-2 supervisors in order to facilitate the flow of information and collaboration between the different stakeholders. This was further supported by the student association SOLAR, which organized various activities for students to meet and share

their experiences. The construction project brought together a pool of architects, engineers and communicators working in an integrated design approach to obtain an innovative result adapted to the format of the competition in a short period of time.

Through their participation in such an ambitious and interdisciplinary project of co-creation, students gained a unique hands-on experience on the challenges of interdisciplinarity and acquired both specific and transversal competences to work towards concrete deliverables pertinent to some of today's most pressing challenges.

4.4.2.2 Swiss Living Challenge Project

The [NeighborHub](#) designed and built within the Swiss Living Challenge project improves community cohesion due to its emphasis on a collective responsibility for sustainability. It encourages its users to showcase new objects and technologies, to learn by experience and to plan collaboratively.

In the short term, the NeighborHub aims to raise the awareness of the neighborhood's inhabitants of their role in reaching environmental goals by acting on seven driving themes: renewable energy, soft mobility, biodiversity preservation, choice of materials, and local food, water and waste management. In the long term, the goal is for the community to self-own the different technologies integrated in the NeighborHub and to implement them at their own scale. To reach this objective, the NeighborHub integrates low-tech solutions such as solar dryers, self-built technologies such as homemade solar thermal panels and a self-taught approach, thanks to an interactive user interface.

The NeighborHub combines atypical solutions developed through an iterative and multi-disciplinary process, which re-

quired development of novel prototypes for many of the systems such as its modular construction approach, a technical donut, dry, worm-composting toilets and integrated façade doors that manually open upward to open up to the neighborhood, manage ventilation during the summer and give the built-in solar panels an optimal angle for power generation. In other cases, such as for the development of the dual thermal strategy, the solar installation and the electricity management algorithm, the results of modeling software were used to guide design choices. One of the NeighborHub's most visible innovation proposals was the positioning of the 29 PV panels exclusively on the East, South and West facades, which relied on a new type of power optimizers to continuously track and adjust the performance of photovoltaic cells. Daily average production was, as a result, not fully concentrated at mid-day and followed a smoother curve throughout the day, with an increase of electrical supply in the morning and evening when peak consumption occurs. The right balance between high-tech and low-tech was certainly one of the keys to this project's success.

4.4.2.3 Objectives and Outcomes

Beyond the desire to participate in a major interdisciplinary competition, the project had several objectives related to the different actors and partners in the project:

- *Pedagogical Objective* – The project was a unique opportunity for many students to participate collaboratively in the design of a complete innovative building in a multidisciplinary context. ENAC considers it essential to provide the new generation of architects and engineers with the tools needed to integrate efficient and sustainable energy systems into construction projects.
- *Innovation and Technology transfer* – The project stimulated laboratories and start-ups of partner institutions to present new technologies within a functional project with high visibility. Many local companies amongst the 48 project partners of the project built new relationships with students involved in the project, as well as with the institutions behind them.
- *Raising Public Awareness* – The project was a powerful means to raise awareness of sustainable housing among the general public. Grounded on two Switzerland-specific foundations, namely the Law on Territorial Development (LAT) and the vision of the 2000 Watts Society (part of the national energy strategy), the project demonstrated functional and viable solutions within a highly innovative building.

4.4.3 SKIL – Student Creativity and Innovation Laboratory

The greatest potential for improving EPFL's quality and visibility as an educational institution clearly lies in the manner with which we interact with our student body. Today, and in the foreseeable future, the best and most relevant engineers, architects, and scientists will be those that, in addition to having a strong base of technical knowledge, are also trained to structure ideas into new constellations and concepts, take initiatives, innovate, work together in groups and across disciplines, and have the courage and self-confidence to lead and inspire.

For this reason, and building upon the experience gained through the ENAC-led Solar Decathlon project across EPFL

– and the curricular and infrastructure gaps it identified – ENAC has taken concrete steps to modernize its curriculum and learning infrastructure. A fundamental step in this process has been the establishment of [SKIL](#), which is a custom-made workshop space (Figure 4.32) in which students (mainly second and third year Bachelor and Master students) can work on projects that they either define themselves, or have a great freedom in formulating. In SKIL, the students are strongly encouraged to be creative, innovate, and engage interdisciplinary group work. SKIL thus promotes a new culture for hands-on and bottom-up projects, for which the students receive grades and credits.

4.4.3.1 Infrastructure

SKIL, which was launched in the spring of 2018, contains a broad selection of tools for working with plastic, wood, textiles, electronics, etc., as well as equipment such as: 3D printers, laser cutter, CNC milling machine, computers with software for drawing/designing/app development, sewing and embroidery machine, etc. Users of the SKIL have to complete a [training course](#) before being allowed to access these tools. The theoretical training focuses on the rules of use including a reminder of emergency measures in case of accident, information on the risks to which users are exposed and the measures to be taken to avoid them. Even in its star-

tup phase, an average of 50 students per week came outside of credited courses for their own projects during SKIL's first semester.

SKIL complements the ecosystem of maker and workshop facilities for students on the EPFL campus, which includes the [Atelier des maquettes](#), the [Discovery Learning Laboratories](#), the [SPRING](#) workshop, the [ATPR](#) mechanical workshop, the [Robopoly Association](#) and other well equipped labs and workshops.



Figure 4.32. Workshop space within the SKIL building.

4.4.3.2 Pedagogical Framework

The SKIL environment has the ability to support projects defined entirely by small teams of students or larger, thematic and interdisciplinary projects, and is already fully integrated as a work environment for ENAC's Design Together program, in which students from all three institutes within ENAC blend together to work on highly interdisciplinary projects. SKIL also supports several other courses in prototyping and innovation, which bring together students from all over the EPFL campus and even the nearby University of Lausanne (UNIL) and Ecole Cantonale d'Art de Lausanne (ECAL).

The list of credited courses that have taken place or been supported by the SKIL since its launch in the Spring of 2018 include:

- ENAC teaching unit SKIL Student Kreativität and Innovation Laboratory ([PENS-315](#), 4 ECTS)
- SHS Prototypage ([HUM-375](#), 2 ECTS)
- SHS Creativity and Inclusive Design ([HUM-378](#), 2 ECTS)

All activities in the SKIL are supervised by coaches in the form of highly qualified technical and academic personnel. The concept of a coach, as opposed to a teacher, is fundamental to SKIL's vision. Indeed, the role of the coaches is to inspire, guide, facilitate, advice, and interact – but not to lecture. Lecturing, i.e., the standard top-down approach to teaching is strongly discouraged in SKIL, which is designed to break with this traditional form of teaching.

4.4.3.3 After One Year...

A variety of projects has been realized within SKIL since its start. Amongst these, nine research projects have been carried out after its first semester of existence – one on uses of mycelium¹, an environmentally-friendly shower², a system to recover weather balloons,³ and a community website.

The total number of students who have used SKIL in its first year of existence is around 350, of which 92 enrolled in accredited courses happening in SKIL.

A survey was conducted regarding the students' background and their motivation for using SKIL, which led to the distribution presented in Figure 4.33.

Student motivation for using the SKIL

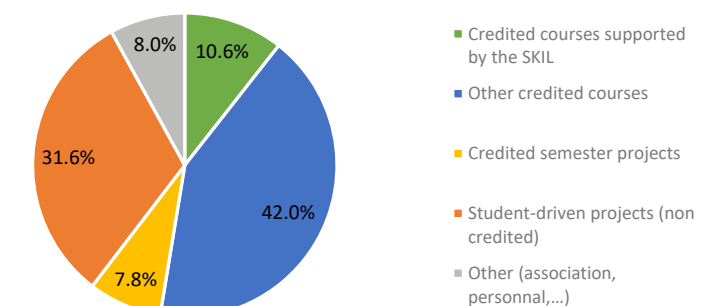


Figure 4.33. Student motivation/background for using the SKIL infrastructure.

4.4.3.4 Outlook

As SKIL develops, it is envisaged that coaches may come from all over EPFL and include professors, EPFL collaborators (lecturers, technicians, members of the Tech Transfer Office or the EPFL library, etc.) and students (PhD, MA or possibly BA). It is the intention that student coaches will obtain teaching credits for time spent in SKIL. Coaches may also be scientists, engineers, or technical personnel from EPFL's Innovation Park or from companies with EPFL alumni on their staff. Any coach in SKIL has a unique opportunity to scout for

talent among the students. It is expected that strong links will be formed very early between students and coaches, directly contributing to binding people together and aiding in the formation of an even more closely connected EPFL community. Thus, SKIL is, in essence, the physical framework for bringing together students from all over EPFL and thereby creating a new, strong culture for student-driven and hands-on projects, which complement the obligatory, discipline-oriented courses.

¹ <https://actu.epfl.ch/news/the-mushroom-that-works-like-a-green-3d-printer/>

² <https://actu.epfl.ch/news/showerloop-lets-you-take-a-full-shower-with-just-1/>

³ <https://actu.epfl.ch/news/a-clever-way-to-recover-weather-balloon-radiosonde/>

4.5 Continuing Education

ENAC faculty members contribute strongly to the continuing education opportunities provided at EPFL. The training is either offered as a certified program leading to a degree such as the Master of Advanced Studies (MAS) or different type of non-degree programs such as short-term training courses, open modules or Massive Open Online Courses (MOOCs).

Today, [16 MOOCs produced at EPFL](#) are taught by ENAC researchers from all three Institutes. Five others are currently in production. The courses are provided in French, English or both languages on different platforms such as Coursera, edX or the Swiss MOOC platform Courseware.

The following EPFL MOOCs taught by ENAC researchers are currently available:

- [A Resilient Future – Science and Technology for Disaster Risk Reduction](#)
- [Economie du Sol et de l'Immobilier I](#) and [II](#)
- [Éléments de Géomatique](#)
- [Exploring Humans' Space: An Introduction to Geographicity](#)
- [Groundscape Architecture Design Lab. Re-thinking Cities Underground](#)
- [Housing and Cities](#)
- [Intelligent Transport Systems](#)
- [Introduction aux Systèmes d'Information Géographique – Partie 1](#) and [2](#)
- [Introduction to Discrete Choice Models](#)
- [L'Art des Structures I : Câbles et arcs](#) and [II: Treillis, poutres, dalles et cadres](#)
- [Mobilité et urbanisme](#)
- [Planification des mobilités](#)
- [Villes africaines : Introduction à la planification urbaine](#)
- [Villes africaines : Restructuration des quartiers précaires](#)
- [Villes africaines : Environnement urbain et enjeux de développement durable](#)
- [Villes africaines : Mobilités et transports urbains](#)

In the framework of the [EPFL-UNIL continuing education](#) program, ENAC researchers provide a course leading to a MAS degree on Expertise dans l'immobilier and several short courses, such as on Energy Geostructures Analysis and Design, Discrete Choice Analysis: Predicting Demand and Market Shares, and Evaluation de la qualité écotoxicologique des sédiments. A degree course on Urbanism is furthermore offered by the University of Geneva, leading to a joint MAS degree from EPFL and the University of Geneva (section 4.5.1).

In addition, scientists from all three ENAC institutes are also regularly involved in postgraduate courses and professional training offered other academic and non-academic institutions, or to professionals in a field.

ENAC has developed two continuing education programs, which deal with territorial issues and make it possible to train EPFL students in urban planning and design.

4.5.1 Master of Advanced Studies in Urban Planning and Design

Noting that urban planning is, by definition, a multidisciplinary endeavor and that social science competences are strongly represented at the University of Geneva, EPFL and the University of Geneva started a new [MAS](#) in this area in September 2018. The main objectives are to enable students to update their knowledge on new developments in contemporary urbanism, to allow the acquisition or consolidation of technical and methodological skills (information systems, urban project planning, territory diagnosis, etc.), to be able to use tools of project management combining several professional skills, and to update knowledge on regulatory as-

pects of urban planning. The MAS is made up of four CAS (Certificate of Advanced Studies, an independent qualification) elements:

- Themes and Scales of Urban Planning
- Urban project and spatial planning
- Geographic information systems in urban planning
- Urban planning and actors

The four CASs are followed by a final dissertation to obtain the MAS.

4.5.2 Certificate of Open Studies: Management and Planning of African Cities

The [MOOCs4DEV](#) program supports the development of courses and their implementation in African universities. The aim of this program is to use digital technology to improve the quality of higher education in sub-Saharan African universities to enable future graduates to successfully integrate it into the professional world.

This program was launched in 2013 at EPFL and is the result of a public-private partnership between EPFL, the Swiss Agency for Development and Cooperation (SDC) and the Edmond de Rothschild Foundations. It relies on the member institutions of the Network of Excellence of Engineering Sciences of the Francophonie ([RESCIF](#)).

As part of this program, ENAC has developed a [COS in management and planning of African cities](#), which is composed of a theoretical part, in the form of MOOC courses and a practical part, in the form of personal work. Both can be done remotely and online as part of continuing education programs. It is possible to follow and obtain the certificate without any academic degree.

On average, a workload between 560 and 600 hours is necessary over a period of 1 to 2 years. After passing the examination, a Certificate of Open Studies (COS) is issued by EPFL. The themes are those of the management and planning of African cities with a focus on tools such as GIS.

5. Research

5.1 Overview

The three ENAC Institutes are responsible for defining, organizing, generating and carrying out research relevant to their fields. In this sense, they are the key structural elements that nurture and support their component laboratories. They are responsible for developing profiles of new professorships, for creating and managing facilities and platforms, and for overseeing space allocations. Each Institute is, in terms of faculty, largely aligned with their corresponding Section, thus ensuring synergy between research and teaching dimensions in their domains.



5.2 Institute of Architecture and the City (IA)

5.2.1 Overview

The Institute of Architecture and the City (IA) currently comprises 21 laboratories and 3 groups:

- ACHT – Architecture, Criticism, History and Theory – Prof. Christophe Van Gerrewey
- ALICE – Design Studio on the Conception of Space – Prof. Dieter Dietz
- CEAT – Urban and Regional Planning Community – Dr. Jérôme Chenal
- CNPA – Laboratory of Digital Culture for Architectural Projects – Prof. Bernard Cache
- EAST – Laboratory of Elementary Architecture and Studies of Types – Profs. Anja & Martin Fröhlich
- FAR – Laboratory of Construction and Architecture – Prof. Paolo Tombesi
- FORM – Laboratory for Architecture as Form – Prof. Kersten Geers
- LAB-U – Laboratory of Urbanism – Prof. Paola Viganò
- LABA – Laboratory Basel – Prof. Harry Gugger
- LAPIS – Arts of Sciences Laboratory – Prof. Nicola Braghieri
- LAST – Laboratory of Architecture and Sustainable Technologies – Prof. Emmanuel Rey
- LASUR – Urban Sociology Laboratory – Prof. Vincent Kaufmann (joint with IIC)
- LCC – Construction and Conservation Laboratory – Prof. Luca Ortellì
- LDM – Media and Design Laboratory – Prof. Jeffrey Huang (joint with IC)
- LEURE – Laboratory of Environmental and Urban Economics – Prof. Philippe Thalmann
- LIPID – Laboratory of Integrated Performance in Design – Prof. Marilyn Andersen
- LTH2 – Theory and History of Architecture Laboratory 2 – Prof. Bruno Marchand
- LTH3 – Theory and History of Architecture Laboratory 3 – Prof. Roberto Gargiani
- MANSLAB – Laboratory for Spatial Manufacturing – Profs. Marco Bakker & Alexandre Blanc
- SXL – Structural Exploration Lab – Prof. Corentin Fivet (joint with IIC)
- TSAM – Laboratory of Techniques and Preservation of Modern Architecture – Prof. Franz Graf
- GR-ACM – Archives of Modern Construction – Dr. Salvatore Aprea
- BUILD – Building 2050 – Dr. Sergi Aguacil

IA also enjoys operative affiliations with the following ENAC laboratories:

- CCLAB – Composite Construction Laboratory – Prof. Thomas Keller (IIC)
- GR-GN/BPE – Bioenergy and Energy Planning Research Group – Prof. Edgard Gnansounou (IIC)
- HOBEL – Human-Oriented Built Environment Lab – Prof. Dusan Licina (IIC)
- IBETON – Structural Concrete Laboratory – Prof. Aurelio Muttoni (IIC)
- IBOIS – Chair of Timber Construction – Prof. Yves Weinand (IIC)
- LASIG – Geographic Information Systems Laboratory – Prof. Francois Golay (IIE)
- LESO-PB – Solar Energy and Building Physics Laboratory – Prof. Jean-Louis Scartezzini (IIC)
- TEBEL – Thermal Engineering for the Built Environment Laboratory – Prof. Dolaana Khovalyg (IIC)

Institute laboratories also contribute to the activities of different EPFL Competence Centers, such as the Habitat Research Center (HRC) (section 2.5.3.2) and the Transportation Center (TRACE) (section 2.5.3.1), the Energy Center (CEN) (section 2.5.3.3) and the Cooperation and Development Center (CODEV) (section 2.5.3.5), as well as to the inter-institutional research center Smart Living Lab (SLL) in Fribourg (section 2.5.1.1).

5.2.2 Personnel

The faculty is currently composed of

- 8 full professors
- 12 associate professors
- 2 assistant professors (tenure-track)
- 1 adjunct professor
- 4 senior scientists

Since the last audit, in 2011, the work landscape of the Institute has changed significantly: 9 of the 18 laboratories that formed its structure at the time no longer exist, whereas 12 of the current laboratories were established after 2011 (Figure 5.1)

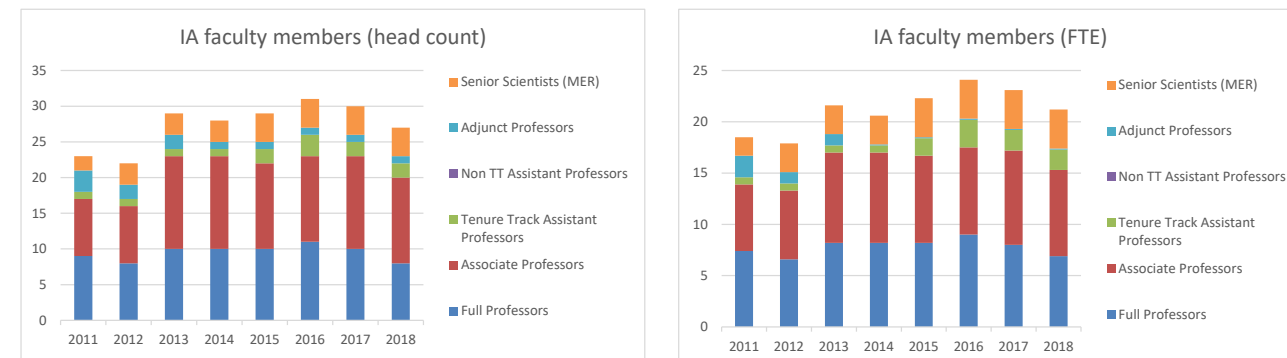


Figure 5.1. Evolution of IA faculty members since 2011. (Left) Head count. (Right) Full Time Equivalents (FTEs). TT = Tenure-Track, MER = Maître d'enseignement et de recherche.

5.2.3 Research Portfolio

Research horizons and pathways across the scholarly landscape defined by the broad membership of an Institute dealing with Architecture and the City are naturally varied and in principle specialized. They concern diachronic analyses of the built environment in its various forms as well as humanistic and applied science investigations into contemporary topical issues. Characteristically, a significant part of the work is conducted in conjunction with teaching curriculum activities, often producing publications that superimpose research concerns and pedagogical strategies. By and large, the activities of the Institute can be grouped around five domains, useful to define cultural or methodological affinities

but not exclusive of possible collaborations across sub-disciplinary fields:

- Theory and History
- Construction and Sustainable Development
- Art and Expression
- Territory and Society
- Projects and Design

Each domain can be seen as the institutional clustering that establish specific relationships between urbanism and the world in which it develops.

5.2.3.1 Theory and History

The Theory and History domain, currently comprising 4 laboratories (ACHT, LTH2, LTH3, TSAM) and 1 group (ACM), investigates the relationship between architecture and society – at cultural, technological and social levels: how we recognize architecture, how we discuss it, how we position ourselves against it, how we intervene in it. Research undertaken by the members of this cluster is concerned with seminal figures of the architectural debate, prevalently in Europe and Switzer-

land, with materials' architectural history, with building conservation and reuse challenges in modern architecture, and with typological characters and transformations. Since last Audit, the cluster has witnessed significant changes with the retirements of Profs. Lucan (LTH1) and Frey (ACM). The ensuing changing-of-the-guard has brought in academics with different profiles, thus triggering natural modifications in focus and methodological strands.

5.2.3.2 Construction and Sustainable Development

The relationship between design and industry, and that between design and building performance, are investigated within another cluster of four laboratories (FAR, LAST, LIPID, SXL) and one group (Building 2050). The Construction and sustainable Development cluster increased in size and scope since the 2011 Audit, with the additions of FAR and SXL. Here,

challenges of sustainability emerging within architecture and urban design-centered frameworks are tackled using multi-scalar approaches, by following the experimental tenets of scientific research, and by adopting socio-technical readings of the building industry. Research foci include:

- Transcription of sustainability principles across different levels of intervention – from urban design to building components – to delineate innovative evaluative criteria for architectural design
- Interactions of energy, health, comfort and perception aspects in the design of the built environment, with an overall strategic goal of fulfilling building occupant needs
- Definition of a proper 'architecture' of the building sector, which enhances the uptake of novel spatial ideas to be constructed and for industrial circular economies to develop
- Energy/carbon performance of buildings and design strategies necessary to achieve consumption requirement levels.

5.2.3.3 Art and Expression

Issues of communication in architecture are explored within the Art and Expression grouping, an ensemble of three laboratories (CNPA, LAPIS, LDM) that were in the process of definition at the time of the 2011 Audit. A fourth laboratory – Informatics and Visualization (LIV) – was recently closed following the retirement of its director. This grouping investigates the simulative and visualizing potential of art techniques, including technological media and cultural languages. On one hand, the work of the cluster betrays an interest in the organizational structure of data. On the other, it studies both the messages embedded in it and the effectiveness of the

information generated from them. Technology and culture constitute the dialectical elements of the work, with different researchers investigating:

- Transpositions of conception and fabrication methodologies from industry to architecture
- The value of emotional approaches to figuration in scientific fields (thus defined by objectivity)
- Effects of bringing physical and virtual environments together at urban scale

5.2.3.4 Territory and Society

The Territory and Society domain brings together the largest number of research units within the Institute, 5 laboratories (LABA, LAB-U, LASUR, LCC, LEURE) and 1 group (CEAT). Since last Audit, the cluster has witnessed significant changes, particularly in light of the retirement of Prof. J. Lévy (Chôros). Territory and Society seeks to articulate specific relationships between the availability of physical space and the uses made of it. This is done via a number of analytical filters:

- Mobility of the actors inhabiting a territory
- Ability of social groups to connect experiences and organize actions based on them
- Type of building artifacts generated in and by specific places
- Ability of territories to renew themselves by giving rise to different spatial patterns
- Analysis of certain moments in the history or urbanization and their typical value
- Analysis of the financial and environmental resources employed in the process.

5.2.3.5 Project and Design

The relationship between the organization of space and the employment of material strategies is explored in Project and Design. This cluster's activities have profoundly modified since the 2011 Audit, with the progressive departure of five laboratory directors (Profs. Mestelan, AIC; Lamunier, LAMU; Bassi, LAURE; Staufer and Hasler, LABEX; Berger, UTA), the repositioning of two in other areas of concentration (Ortelli, LCC and Huang, LDM), and the establishment of four new laboratories (Fröhlich, EAST; Geers, FORM; Bakker and Blanc, MANSLAB; Perrault, SUB – soon to be increased by two more to replace the laboratories of Lamunier – LAMU – and Perrault – SUB). Due to the idiosyncratic nature of the work, investigation agendas and methods differ substantially.

Over the last eight years, architectural explorations have been organized in relation to six main axes:

- Inhabitation experiences of bodies in space
- Determinants of use patterns and technical patterns in buildings
- Inhabitation potential of basic architectural geometries
- Contributions of craft and know-how to architectural solutions
- Role of programmatic complexity in large-scale design
- Ground-excavated architecture as material reflection of contemporary concerns

5.2.4 Scientific Output and Scholarly Impact

Overall research activity outcomes within architecture are not easily gauged by traditional bibliometric indicators used in science and engineering, as the low indexing rate of relevant architectural and urban design publications – less than 20% of the total – makes it difficult to use it as an accurate measurement of the work actually produced by built environment researchers as a whole. In fact, notwithstanding the strong publication impact factors of certain laboratories active in specific fields of research, bibliometric information from traditional datasets portrays an image of productivity for IA that is lower than its ENAC counterparts – IIE and IIC, with architecture, urban studies and geography sub-fields specifically providing the lowest values, both in terms of published items and citations. Monographs, which play a major part in the output of IA laboratories, are typically excluded from these types of indicators although they represent an essential part of how scholarly work in architecture is actually disseminated. As a whole, IA has produced over 65 scholarly books since 2011 with international publishers or distributors, and another 49 produced that featured research carried out with students and as part of teaching activities. Once this produc-

tivity is accounted for, the different Institutes within ENAC and beyond become more comparable.

Output and impact within IA take other important yet not entirely indexable forms. A laboratory of IA (LTH2) produces and edits *Revue matières*, an influential scholarly outlet for architectural studies in French, established in 1997. Another laboratory – FORM – co-founded and has been actively contributing to the highly renowned Italian-based international architectural magazine *San Rocco*, first launched in 2010. Yet another laboratory, LaSUR, produces and edits *Espace-Temps.net*, an open, interdisciplinary and international journal of social sciences and urbanism. Leadership in these activities have a noticeable impact on the disciplinary culture at large.

Documentation of the work produced by IA's architectural design laboratories is also of note. Within the 2012-2019 timeframe of the current review, 14 monographs were published on related design and building activity. Across the same period, another 19 featured the work of IA visiting professors.

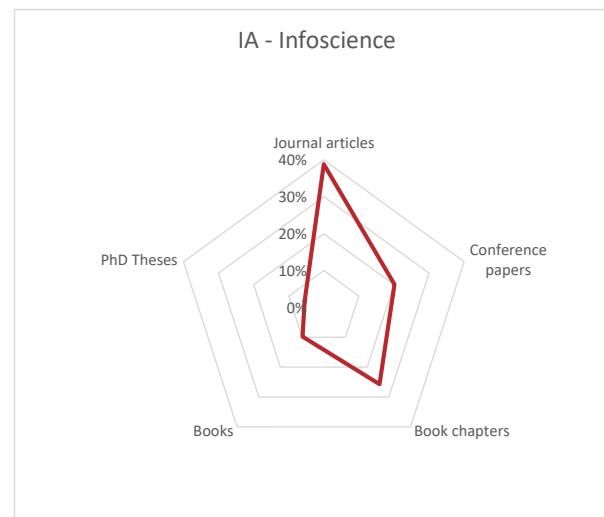
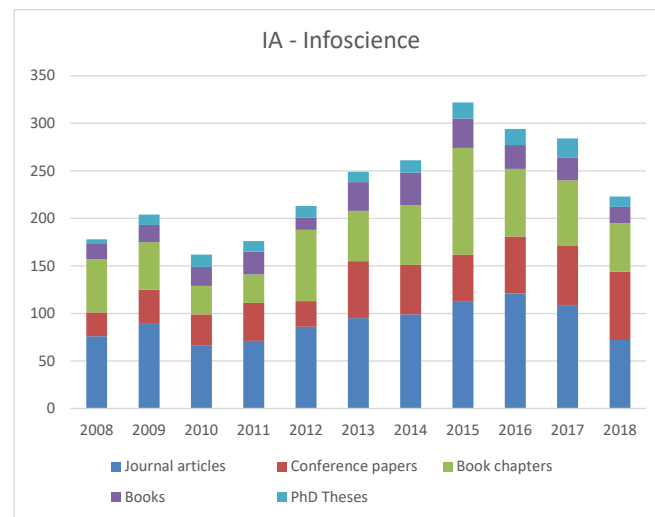


Figure 5.2. (Left) IA publications in Infoscience (no filters applied). The category «Journal articles» includes both original research papers and reviews. (Right) Spider plot of the type of publications produced by IA from 2008-2018.

5.2.5 Inter- and Multidisciplinary Collaboration

Interdisciplinarity is commonly practiced within IA, due to the presence of multiple specialist areas within the same administrative structure and the same physical premises. The Territory and Society domain (section 5.3.3.4) is possibly the area where most laboratories converge to work on common research platforms that offer opportunities for inter-Institute collaboration as well (i.e., between IA, IIC and IIE). Territory and Society is currently also the notional address for the doctoral program EDAR (section 4.3.3), which provides a gravitational center for PhD program-related seminars that can originate from different parts of IA but always involve research students belonging to multiple laboratories.

Interdisciplinarity is inherent the mission of the Smart Living Lab in Fribourg, which foresees research interactions between units of IA and IIC, and between ENAC and the other academic partners of the Smart Living Lab specializing in a wide range of topics, from urban design and energy, to construction law and innovation management. The NeighborHub, winning entry at the U.S. Solar Decathlon 2017 competition (section 4.4.2), can be considered as a leading example of the integrative opportunities offered institutionally

and by the facility.

At both the Bachelor and Master curriculum levels, IA takes part in the Design Together program (section 4.4.1) by offering a large number of ENAC weeks, ENAC Teaching Units and ENAC semester projects, a research-focused curricular unit offering Master students opportunities to apply and consolidate their theoretical knowledge to plan and realize interdisciplinary research projects. Currently, IA has 16 research projects running that involve Master students from multiple disciplines.

Across ENAC, interdisciplinarity is facilitated by the existence of competence centers with explicit investigation mandates into complex issues. Led by IA, the Habitat Research Center (section 2.5.3.2) is the natural research abode for investigating urbanism. The Center involves laboratories from all ENAC Institutes, and reaches out to other faculties through collaboration with Computer Science and Digital Humanities (e.g., [DHLab](#)). The Transportation Center (section 6.2.2) is also a place where several IA laboratories – CEAT, LASUR, LEURE – practice transdisciplinarity.

5.2.6 Vision

As the preceding sections articulate, IA stands tall on a deep and consolidated foundation of intelligence and scholarship, developed over many years in multiple areas that are as important to urbanism as a technical and humanistic endeavor as they are specific in relation to their own disciplinary statutes, including:

- Architectural pedagogy
- Aesthetics
- Architectural design and history
- Building systems
- Environmental management and computing
- Graphic communication
- Land occupation and use
- Inhabitation patterns
- Urban economics
- Social behavior and flows

The levels of excellence and recognition achieved by the Institute's faculty in each of these areas make it natural to continue working within trails that have been clearly marked by academic success. At the same time, the increasingly complex and systemic challenges arising from the evolving dynamics of urbanization and its multi-domained variables call for a different type of disciplinary effort, where knowledge specialisms add onto one another in search of breadth, critical mass, contradictions and internal dialogue. On this basis, IA will endeavor to overcome the cultural separation that

distinguishes its internal lines of academic work by striving towards their intellectual and operative integration at a higher level. To form this new identity, the underpinning idea of multidisciplinary will be tackled hermeneutically, so as to be transformed into a new, self-standing intellectual paradigm that is not the result of incremental additions but rather deep integrative, and ultimately self-effacing, work.

The idea of an architectural research institute, in this context, is to give rise to an ulterior understanding of architecture that, without replacing traditional epistemologies and exegetic grounds, presents us with the tantalizing possibility of a new discipline, operating at the macro level as an ecosystemic organizer of cultural readings, social identities, material resources, community aspirations and well-being, spatial morphologies and languages, technological strategies and applications, environmental concerns and actions, industrial transformations and economic balancing. It is only by entering and structuring all of this in a physical and communicable way that we can aspire to reclaim the emancipatory function that was once distinctive of a modern idea of architecture, but is now called justifiably into question by the upscaling of concerned territories, the broadening of human habitat issues and the social proliferation of agencies.

The premises of this vision reside in the Institute's eventual capacity to respond positively to the following provisions:

- Engage with environmental readings that increase in cultural and methodological complexity vis-à-vis current internal practices
- Take advantage of evolving technical tools
- Develop an ability to generate productive syntheses of concurring conditions
- Carry out evaluative exercises that integrate theory with plans of action
- Pursue strategies of disciplinary contamination that combine exact science, applied science and humanities
- Develop integrated responses to each of the above dimensions
- Act as public agency

In this critical, self-reflective yet assertive attempt to gauge and calibrate contemporary notions of progress in environmental studies and action, individual IA components have critical roles to play, notably:

- *History – In support of all* – Given the iterative nature of building, history constitutes the natural repository of design experiences and lessons. As such, and considering its inventory potential, it is set to provide an essential compass to navigate the land of the new. With its recognized pedigree, history at ENAC will continue its investigations into the material and spatial aspects of building while widening its focus to its social and environmental aspects. This will provide a basis for the work of applied sciences within IA, and will help discerning innovation trajectories over time. New dedicated chairs are expected to become available in three years. The contribution of history to the non-historical activities of the Institute will be made tangible in the intervening period by establishing principles of complementarity with investigation foci in regional, environmental, technology and visual studies.
- *Theory – Definition of meaning and assignment of value* – Based on theory, IA will metabolize the distance between documented pasts and examinable presents, and will elaborate conceptual corollaries to future action. The function of theory at ENAC will thus be one of agenda definition and interdisciplinary coordination, which will take its moves from an understanding of relevant environmental parameters and the ability to assign meaning and value to specific courses of action. The type of theoretical activity implied in this description has indeed characterized particular points in the history of architecture as a discipline; so, a new chair (due to faculty retirement) will seek to function as the pivotal element in the articulation of emerging architectural paradigms.
- *Technology – Assessment of design hypotheses* – Because of its empirical approach to environmental analysis, technology will have to function as a data provider for evaluative exercises and simulative efforts. As part of this function, it will have to act, experimentally, as the Institute's critical conscience of innovation and its rationales. Fulfilling this mission will require clarification of the contextual role of testing and prototyping, reflection on the distance between manufacturing possibilities and the anthropology of construction, consideration of the socio-technical variables contributing to products' lifecycle performance and, ultimately, the opening up of conventional notions of sustainability to scrutiny and criticism from other components of IA.
- *Social Sciences – Articulation and rationalization of differences* – A core aspect of social sciences is the injection of reality into otherwise fundamentally speculative exercises. Yet, rather than acting simply as a validation rubric, societal knowledge and investigation should provide context for the range of environmental behaviors and actions at the building fabric level. Reflective monitoring of human activity, in other words, should be put at the service of building program definition that considers culture, locale, needs and constraints. This will form a strategy to conceive the context of design intervention across IA by the intensity of given parameters rather than by geographic or socio-economic zones, as is the case today.
- *Building Design – Embodiment of diversity* – In the IA vision, building design will have both catalytic and representative functions. As the ultimate instrument for the structuring of space and the organization of its activities, building interventions will become the embodiment and crucial reflection of the Institute's ability to assemble dis-homogenous data and disparate scholarly cultures, evaluate complex material alternatives and their implications, and propose original syntheses of all the variables at play. The recent selection process for two new architectural design positions within IA made it clear that this is a mission understood and embraced by the professional community of reference. Hence, building design will become a powerful medium giving shape to the research work of the entire Institute, thus clearly differentiating its output from that of concurrent institutions.

- *Data Management – Creation of true complexity* – In the architecture of this macro-system, data connectivity and graphic communication will play a central instrumental role. Digital bridging and the computational translation of building-related data are necessary to ensure the proper widening of analytical scope, thus adding the possibility of epistemological enrichment to the landscape under analysis and the parameters utilized for comprehending and intervening in it. Moreover, with time retaining significance in understanding ecological evolution, our ability to delve in history scientifically via digital humanities, to produce multivariable robust simulations that can be examined and compared with the present, provides an invaluable instrument for understanding progress (or its vagaries) in our habitats. The recent retirement of one professor in Communications allows us to envision possible ways to respond to the challenges and opportunities of data creation and transfer in architecture, whilst considering also the epistemological and technical issues already informing the work of other ENAC laboratories.

- *Visual Communication – Design of language* – The hypothesis of a new project for architecture, at a larger scale and with a broad constituency, cannot leave aside the importance of a visual arts component in the economy of the machine entrusted with its delineation. Expanded disciplinary vocabularies call for the rethinking of communication languages, capable of articulating the complexity of the challenges undertaken and to represent, synthetically, our responses to them. ENAC has always been, and should continue to be, at the forefront of this architecture-as-language definition process. Work on the development of graphic vocabularies will take place within the research unit already focusing on visual expression, but will also be distributed across other laboratories dealing with new types of data sets. Visual communication is indeed an aspect of research that has the potential of establishing a community of contributors within IA.

The institutional construct emerging out of this conceptual expansion process will have acquired an eminently political character as a literal reflection of two its features: (i) the organic integration of multiple strands of knowledge and areas of analysis (e.g., polytechnical); and (ii) the ability to synthesize them into overarching plans of action (e.g., policy). The result will be a strengthening of the public definition of the Institute as a whole, and with it its position in the higher education atlas and broader service ability. Focusing on structures and methods of work rather than subject matters (already treated at the individual laboratory level) will enable IA to span across the territories currently covered by its academic body activities without renouncing its overall identity. The same IA will be able to deal with product innovation and environmental issues in Switzerland, urbanization pressures in developing economies, sustainable development goals globally – thus providing a concrete abode to the official, multi-layered

mission of a Swiss federal technology institute, at both knowledge-generation and knowledge-transfer levels.

The definition of such an architectural guise will also facilitate structural research relationships between IA, IIC and IIE, with the two engineering partners feeding fundamental and specialist applied science to their architectural sibling, and with architecture widening the contextual cone of vision of the research carried out within engineering while creating opportunities for its further development and application.

Against this background, it is not inappropriate to imagine exciting evolutionary prospects for a broadly scoped PhD program in architecture, already present in embryonic form within EDAR and its Complex Design option, which could acquire specificity through transversal outlook, and international exposure through the uniqueness of its offering.

5.2.7 Outlook and Perspectives

The conditions required to realize the vision outlined here are well afoot. While the narrative proposed has its premises in the analysis of the academic demography of the Institute as is – therefore appearing plausible from now – the next few years will also generate a raft of openings due to academic retirements, at least seven by 2022. This will enable IA to facilitate the implementation of some of its plans by bringing in personalities that, while satisfying the individual scholarly excellence requirements of EPFL, will build on the idea of the Institute as an intellectually collegial entity.

Very soon, we will replace two professors, one in Theory and one in Communications, and these two positions will become the aggregative seeds for the new architectural project. The introduction of Professors of Practice (section 3.2.6) into the teaching structure of the faculty would also add energy and momentum to the plan by enabling IA not only to increase its hiring agility but also to promote, explicitly, the operational potential of its synergetic approach to design by inviting practitioners experienced, or interested, in bringing this vision to fruition.

5.3 Civil Engineering Institute (IIC)

5.3.1 Overview

The Institute of Civil Engineering is composed of 19 laboratories (research groups):

- CCLAB – Composite Construction Laboratory – Prof. Thomas Keller
- EESD – Earthquake Engineering and Structural Dynamics Laboratory – Prof. Katrin Beyer
- GEL – Geo-energy Laboratory – Gaznat Chair on Geo-energy – Prof. Brice Lecampion
- GR-GN/BPE – Bioenergy and Energy Planning Research Group – Prof. Edgard Gnansounou
- HOBEL – Human-Oriented Built Environment Lab – Prof. Dusan Licina
- IBETON – Structural Concrete Laboratory – Prof. Aurelio Muttoni
- IBOIS – Chair of Timber Construction – Prof. Yves Weinand
- IMAC – Applied Computing and Mechanics Laboratory – Prof. Ian Smith
- LEMR – Laboratory of Experimental Rock Mechanics – Prof. Marie Violay
- LESO-PB – Solar Energy and Building Physics Laboratory – Prof. Jean-Louis Scartezzini
- LHE – Environmental Hydraulics Laboratory – Prof. Christophe Ancey
- LMS – Soil Mechanics Laboratory – Chair Gaz Naturel Petrosvibri – Prof. Lyesse Laloui
- LSMS – Computational Solid Mechanics Laboratory – Prof. Jean-François Molinari
- LUTS – Urban Transport Systems Laboratory – Prof. Nikolaos Geroliminis
- MCS – Structural Maintenance and Safety Laboratory – Prof. Eugen Brühwiler
- RESSLAB – Resilient Steel Structures Laboratory – Prof. Dimitrios Lignos
- TEBEL – Thermal Engineering for the Built Environment Laboratory – Prof. Dolaana Khovalyg
- TRANSP-OR – Transportation and Mobility Laboratory – Prof. Michel Bierlaire
- VITA – Visual Intelligence for Transportation – Prof. Alexandre Alahi

The following laboratories and groups have a secondary affiliation with the Institute:

- GR-ACM – Archives of Modern Construction – Dr. Salvatore Aprea (IA)
- BUILD – Building 2050 – Dr. Sergi Aguacil (IA)
- LASUR – Urban Sociology Laboratory – Prof. Vincent Kaufmann (IA)
- SXL – Structural Xploration Lab – Prof. Corentin Fivet (IA)

5.3.2 Personnel

The faculty is currently composed of:

- 9 full professors
- 5 associate professors
- 5 assistant professors (tenure-track)
- 2 adjunct professors
- 4 senior scientists

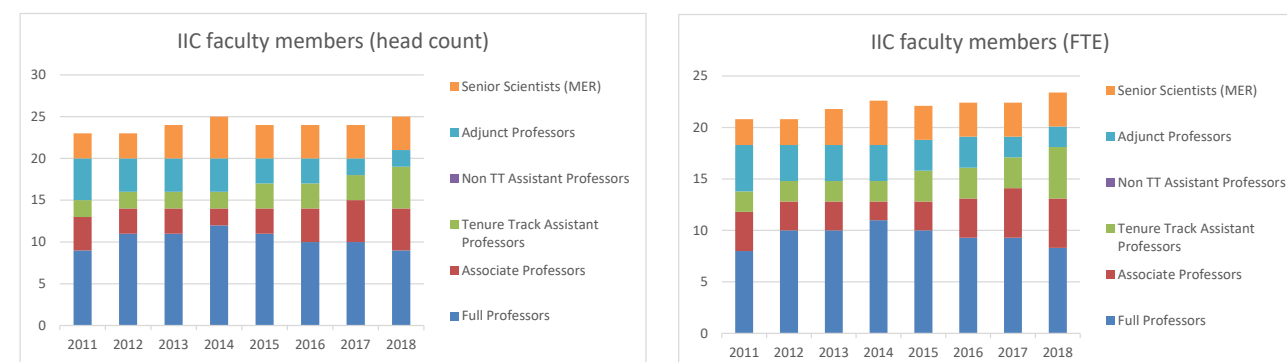


Figure 5.3. Evolution of IIC faculty members since 2011. (Left) Head count. (Right) Full Time Equivalents (FTE). TT = Tenure-Track, MER = Maître d'enseignement et de recherche.

5.3.3 Vision

The civil engineering industry is the largest consumer of raw materials, and constructed assets account for approximately one-third of the world's total carbon emissions. While this situation is unsustainable, society expects civil engineers to continue to provide the necessary conditions for a good quality of life. In the next decades, engineers must find new and innovative ways to design, manage, renovate, and reuse civil infrastructure and buildings to meet societal needs in a changing world.

To address these challenges, research in Civil Engineering is rapidly evolving and is becoming more and more interdisciplinary. The key driver of the vision is sustainability. In particular, the major challenges to be addressed in IIC are:

- *Design under Uncertainty and Scarcity of Resources* – The next decades will bring unprecedented challenges for civil engineers and meeting them requires scientific competence at the highest level. Urban population growth, resource scarcity and climate change will create situations where traditional civil-engineering practice is no longer appropriate. While civil engineers have strived to do more with less, they now need to do this proactively in challenging contexts of high environmental uncertainty and limited material availability. The Institute will meet these challenges by research efforts in shared mobility systems, development of new materials with beneficial properties, decentralized supply of energy, water and construction materials.
- *Energy and Environmental Impacts* – Mitigation of climate change and the energy transition are probably the most important challenges faced by the planet in the coming decades. The Institute will meet these challenges by research efforts in infrastructure for renewable energy, incorporating new materials in facades for control of heat flux, design of demountable infrastructure, 'prosumers' buildings and infrastructure (both producing and consuming resources), storage of CO₂ and radioactive wastes.
- *Resilience of Civil Systems* – Today's cities have intertwined systems involving stocks and flows of energy, information, materials and people. Growing interdependence leads to increasingly critical challenges of resilience. Achieving city-scale resilience requires a difficult blend of engineering science with governance. For example, chain-reaction system failures will increase in the next decades and civil engineers will be asked to develop new strategies for failure mitigation. The Institute will meet these challenges by research efforts in automated fabrication, remote-sensing technology and machine learning techniques, human-centered systems, data-driven operations, mobility-as-a-service (MaaS) and technology-aware transportation infrastructure.
- *Risks and Life-Cycle* – The long-term horizon characterizing the lifecycle of infrastructure and civil systems requires explicit consideration of the associated uncertainties in hazards, materials and systems, with risks that must be assessed and mitigated. At same time, the lifecycle of existing infrastructure must be extended. The Institute will meet these challenges by research efforts in quantification of risk, reliability and uncertainty, assessment of natural hazards, large-scale digital models, cyber security and data protection.
- *Optimization and Recycling* – Designing and building new infrastructure through the evolution of materials, new construction practices and new technologies will remain essential. Still, IIC anticipates a significant shift towards transforming, maintaining, operating and recycling of existing infrastructure. The Institute will meet these challenges by research efforts in optimization of transport networks, digital twins for energy management and predictive maintenance, and additive manufacturing.

A strong research institute requires diversity, critical mass and multidisciplinary, with synergies with all the top disciplines of a polytechnic university such as EPFL. As the important research challenges mentioned above are relevant to all disciplines of Civil Engineering, it is essential to focus on disciplines that are at the core of Civil Engineering, while forging strong connections with other disciplines. Therefore, our detailed vision will be organized around three essential Civil Engineering disciplines for research, teaching and innovation:

- Structures and materials – providing the shelter and infrastructure
- Transportation and networks – providing the mobility
- Geosystems and natural resources – providing the infrastructure for key natural resources

Moreover, in order to address the essential multidisciplinary dimensions, we also explicitly include two additional pillars connecting across ENAC:

- Interface with environmental engineering
- Interface with architecture

The organization of the research into five pillars is designed to build a clear, interdisciplinary profile of the Institute, with potential to make significant impact both on the discipline and beyond. It is conceived to facilitate the hiring strategy, the update of the teaching curriculum, and the promotion of our activities worldwide.

5.3.4 Research Portfolio

5.3.4.1 Structures and Materials

Civil infrastructure resilience under multi-hazards is a major challenge. With the advent of new opportunities in material science, the evolution of automated fabrication, remote-sensing technology and machine learning techniques, the Institute aims to understand and utilize these technologies to embrace community resilience. Some of the Institute's research priorities are:

- **Digitalization** – Digitalization of our built infrastructure is spreading at a fast rate. Digital twins can be effectively used for effective decision-making to reduce socio-economic risks in the aftermath of natural disasters, to exchange reliable information across engineering disciplines through building information modeling, for energy management efficiency and for predictive maintenance. We anticipate information systems going hand-in-hand with the development of cyber security and data protection, placing the users at the center of new business models.
- **Data and Uncertainty Quantification** – Sensing technology is already implemented from in situ measurements of natural and anthropogenic hazards to the final design face of a civil infrastructure project. High-performance computing and high-fidelity computational modeling are domains effectively developed for use in performance assessment of engineering structures. However, risk, reliability and uncertainty quantification in infrastructure diagnostics, automated fabrication and predictive modeling are areas of continuous development to guarantee infrastructure robustness over the service life.
- **Sustainable Design** – Infrastructure sustainability necessitates the development of advanced cyber-physical systems that transform the performance of physical infrastructure, social networks and natural systems (smart cities concept) accordingly. Indeed, modern infrastructure shall be designed and maintained such that it can be demountable for effective reuse of resources, reduction of CO₂ emissions and energy consumption. In this context, new fabrication techniques shall be developed that promote material recycling and can be integrated into effective decision-making for investment in future technologies that maximize, energy management efficiency, infrastructure life-cycle and the quality of human life. In particular, the direct impact of structures and materials selection on human comfort and health must be anticipated.
- **New Materials, Components and Systems** – The development of new materials manifests beneficial properties, which can be exploited for the optimization of structural performance under multi-hazards over the service life. However, the integration of these materials into the design and maintenance of civil infrastructure is particularly challenging. It requires the further development of such materials to address scale effects, additive manufacturing, the impact of uncertainties on structural robustness and the development of computer simulation models and techniques that further our understanding of the physical mechanisms that cause degradation across scales. Long-term effects should be better understood and quantified so as they can be integrated in the design process of civil infrastructure for an enhanced lifecycle. Several of these concepts shall be evaluated through physical testing across scales.

5.3.4.2 Transportation and Networks

The answer to global transportation challenges is not less transport – it is sustainable transport (Ban Ki-Moon, Former United Nations Secretary-General).

Transportation systems are currently experiencing a fundamental transformation in their structure and organization, triggered namely by the pervasiveness of technologies, data and the development of the shared economy. For the transportation of people, the concept of Mobility as a Service is becoming the reference. It has several implications:

- The ownership of private vehicles will decline.
- The dichotomy between private and public transportation will no longer prevail, with the emergence of fleet of shared vehicles, that are considered as in between private and public transportation.
- Transportation systems will not be designed and operated on a mode-by-mode basis, and multi-modal solutions will be organized.
- Vehicle-centric systems, where each public transportation operator move vehicles on a schedule, will become or be replaced by traveler-centric systems, that account for the needs and preferences of the travelers.

Interestingly, the same trends apply to the transportation of goods, i.e., shared mobility, door-to-door services, multi-modality, and customer-centric systems. The specific case of city logistics is particularly important as the growth of online shopping has generated a tremendous flow of parcels through cities. Some of the important research challenges are related to:

- **Technology** – Mobility-related technologies are spreading at a fast rate. In particular, electric and self-driving cars, controlled by smartphone apps, are creating many opportunities for travelers, and bringing new players into the transportation market. However, the integration of these new systems in our societies may be difficult. Self-driving cars may kill people, Uber-like services may generate unfair competition to professional taxi services, and even attract additional demand from public transport creating more congested cities.
- **Data** – Sensors are everywhere, on infrastructure (e.g., surveillance cameras), in vehicles (e.g., GPS), and with travelers (e.g., smartphones). Besides the implications for privacy, the amount and density of mobility-related data that are potentially available is unprecedented. Needless to say, large amounts of data do not necessarily translate into a lot of information.
- **System Design and Operations** – Existing transportation systems are organized by modes of transportation, both at the public (transportation authorities) and private levels (transport operators). New systems, multi-modal in essence, will have to be designed, and the transition from a mode-by-mode organization to a multi-modal integrated system will have to be managed. A system-of-systems approach will be necessary to replace the existing tendency of optimizing individual systems without considering inter-network interactions and limitations.
- **Demand** – Observing, understanding, quantifying and predicting the needs and preferences of travelers, at the individual level, is critical in the context of Mobility as a Service. Indeed, transportation systems will increasingly be supported by human-aware artificial intelligence. Moreover, the provision of personalized information and advice directly to travelers will help them to better understand the consequences of their decisions for themselves, and for the environment.
- **Urban Congestion** – The presence of self-driving cars in cities are forecast to generate heretofore unseen congestion patterns as the share of the time that they spend moving will be significantly higher than that of human-driven vehicles. Also, congestion patterns will also be impacted by shared mobility.

5.3.4.3 Geosystems and Natural Resources

In relation to the densification of the world population into urban conglomerations, increased natural hazards related to climate change and the necessity of an energy transition, geosystems and their relations with natural resources will require radical research innovations in the coming decades.

With the necessary transformation of our society toward a shared and circular economy, the built environment will assume an active role in the supply of natural resources, such as energy, water and recycled materials, at neighborhood, district and regional levels. This will require radical innovations in the construction sector. The need to factor in long-life buildings, infrastructure cycles and guarantee periods dampens the drive for innovation. On the other hand, broader systemic implications arising from digitalization will break down boundaries between demand and supply sectors, as well as leading to transformative impacts in favor of new construction services and methods. Some of the most prominent research challenges to be addressed are:

- **Underground Space Technologies** – In relation to the densification of the world population in large cities, the use of underground space plays a vital role in current urban development. Demands for the planning, design construction and maintenance of underground space are significantly increasing in both developed and developing countries. The Internet of Things and big data analysis have the potential to significantly revolutionize the design and construction of retaining structures, deep excavations, tunnels, and other specific underground structures.
- **Energy Transition** – Mitigation of climate change and the required energy transition over the coming decades directly involves geoengineering notably in association with geologic storage of CO₂, development of geothermal energy, radioactive waste storage, maintenance and development of hydro-power schemes as well as the replacement of coal by natural gas in combination with renewables. Critical investment decisions and public acceptance for these engineering projects require fundamental research in relation to the complex multi-physical, multiphase and multi-scale processes involved, e.g., how stress and fracture creation in rocks interplays with fluid diffusion and impact on the economics of deep geothermal energy, how multiphase flow in porous media affects mechanical response of chemically sensitive soils and rocks used in radioactive waste disposal, how induced seismicity can be controlled during injection at depth, etc. All these questions challenge the current knowledge and understanding of geosystems. Research breakthroughs in this domain necessitate novel laboratory experiments performed under extreme realistic conditions in association with theoretical modeling. As the deployment of in situ measurements remains relatively limited at depth, efforts must also focus on the development of new measurement methods and improve the analysis and use of current technologies.
- **Natural Hazards** – One of the most challenging issues of modern geomechanics and civil engineering concerns protection against natural hazards (earthquakes, floods, landslides, soil liquefaction, debris flow, etc.). This becomes an even more pressing issue as global warming hikes the risk of a number of these hazards (landslides and floods notably). While the principal geomechanical mechanisms controlling the occurrence of these hazards are reasonably well understood, our forecasting and mitigation strategies are severely limited by the lack of knowledge of in situ controlling parameters (e.g., stress, pore pressure, material properties), especially since these parameters are highly heterogeneous in space and time. As a consequence, the assessment of natural hazards is largely limited to the definition of risk zone maps that often clash with economic and/or urban developments. Research needs to focus on providing detailed studies on how heterogeneity of mechanical properties affect the occurrence of such hazards under realistic in situ conditions. Moreover, a breakthroughs in in situ measurements and the associated data assimilation in forecasting models are definitely required.
- **Active Role in the Energy System** – Duties and services provided by buildings and infrastructure are expected to evolve in the future through sustainable and decentralized supply of energy, water and construction materials. The transition from pure consumers to 'prosumers' – both producing and consuming resources in a sustainable way – is underway. Buildings and infrastructure will become energy and resource-providers, and ultimately active hubs in a decentralized system. They will be involved in a bi-directional exchange with other hubs and will differ from today's services provided by tiered organized utilities.

5.3.5 Scientific Output and Scholarly Impact

The annual number of publications of IIC indexed in the Web of Science increased from about 90 in 2008 to about 180 in 2017. The increase has been globally steady, with two exceptions in 2012 and 2015. Overall, these publications were cited about 17,000 times, resulting in a Category Normalized Citation Impact (CNCI) of 1.8. The CNCIs of the individual subject areas covered by IIC are shown in Figure 5.4, revealing an impact above average for all categories.

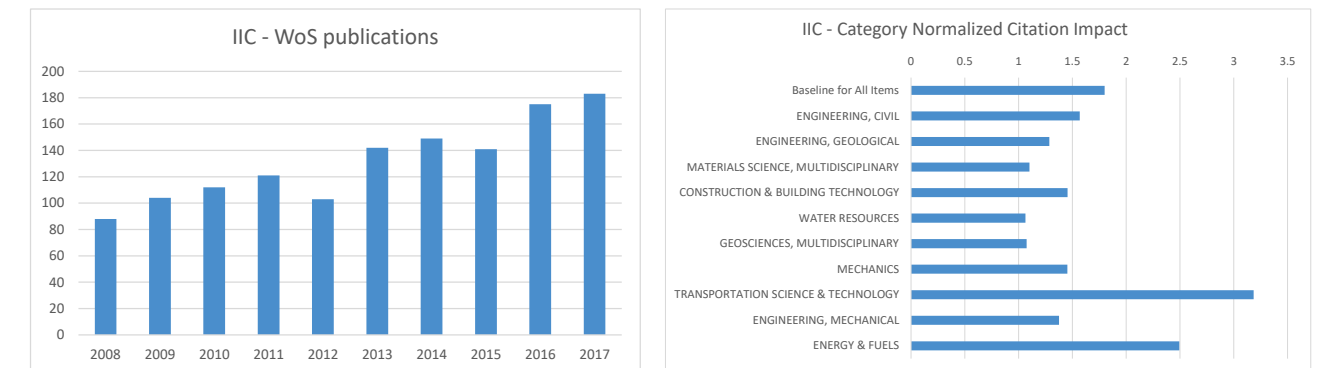


Figure 5.4. (Left) Number of publications authored by IIC faculty (professors and MER) indexed by the Web of Science. Only publications attributed to EPFL are considered (InCites data exported 22 February 2019). (Right) Category Normalized Citation Impact (CNCI) for IIC publications for the period 2008–2017, according to subject category.

According to Infoscience, EPFL's document repository, IIC has increased its scientific production since 2008 (Figure 5.5), with a peak in 2015 (where the number of conference papers almost doubled). This increase is mainly due to a surge in the number of published journal articles, which increased by 40% since 2008. Infoscience lists a total of 4,606 documents deposited during 2008–2018. The vast majority of these documents are journal articles (46%) and conference papers (44%) (Figure 5.5).

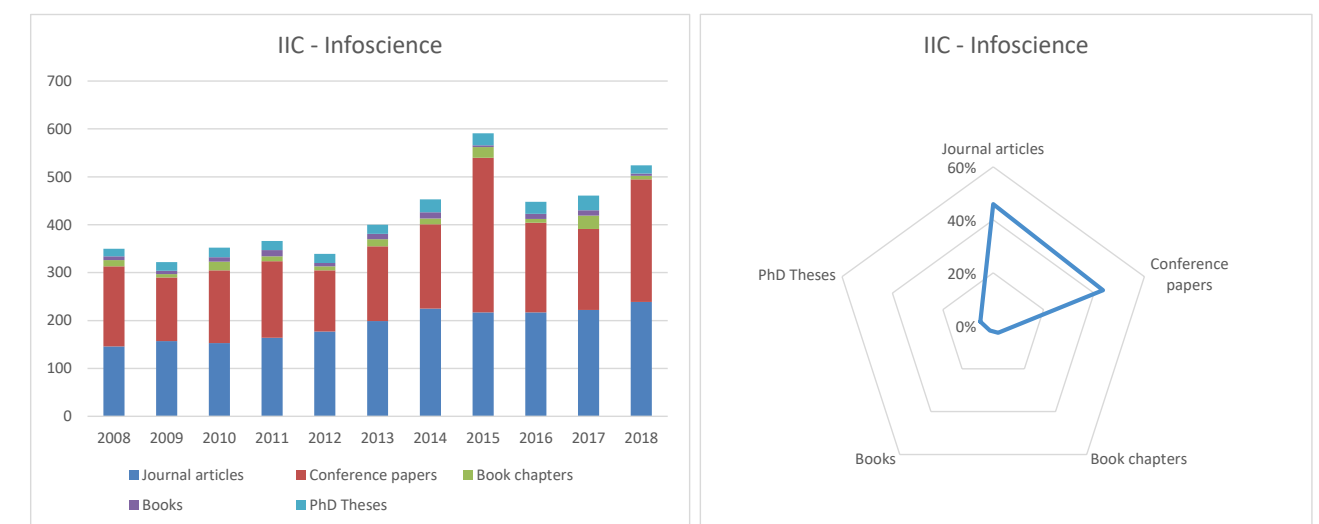


Figure 5.5. (Left) IIC publications in Infoscience (no filters applied). The category "Journal articles" includes both original research papers and reviews. (Right) Spider plot of the type of publications produced by IIC from 2008–2018.

¹ The Category Normalized Citation Impact (CNCI) of a document is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area.

5.3.6 Inter- and Multidisciplinarity

The unique configuration of ENAC provides opportunities for synergies with architecture and environmental engineering. Some important research axes relate to:

- *Smart/Resilient Cities and Communities* – The modification of boundary conditions of cities and districts require intelligent urban planning that responds in an efficient and resilient way to future risks, such as climate change, resource shortages and market-related uncertainties. Urban development strategies that protect populations against negative effects of local temperature rise on health and human comfort must be developed. Topics such as the consequences of climate change and novel market-related uncertainties on indoor and outdoor air quality and thermal environments, the impact of the densification of urban areas on the energy and resources use efficiency, micro-climate and the natural environment, need to be addressed. Urban planning and design must moreover lead to a cost-effective mitigation of CO₂ emissions, as well as preservation of natural resources.
- *Efficient Use of Energy and Resources* – Energy-efficient buildings and infrastructure, mitigation of their carbon foot-prints by replacing fossil fuels with renewables, as well as strategies fostering their renewal rate, are key issues associated with the implementation of the [COP 21](#) agreement. These factors are interdependent, increasing the complexity of the planning, construction and operation processes. Cost-benefit optimization methods, as well as new methodologies and guidelines are necessary to determine the most effective combination of measures to avoid energy and natural resources scarcity.
- *Decentralized Renewables and Energy Systems* – The decentralization of energy and resources supply requires a well-founded knowledge of the related demand and production in terms of space and time, as well as their expected evolution in the upcoming decades at the regional and national scale. Load curves for heating, cooling and electricity with a high spatial and temporal resolution, as well as variations due to climate changes, will have to be considered for urban areas. Urban microclimate models will be required in order to temper the heat island effect using adequate building and infrastructure materials, city greening and optimizing urban planning.

5.3.7 Outlook and Perspectives

The Institute of Civil Engineering will build on its expertise in strategic areas to provide sound engineering solutions for the challenges that will arise over the next decades. The Institute will be carrying this out in the Swiss context of high-quality built and natural environments where innovative solutions can be tested for effectiveness most efficiently. When improvements are realized locally, the chances of success elsewhere are high. Simultaneously, the study and comparison of full-scale case studies from around the world are common in many groups.

ENAC provides unique opportunities to work with architects and environmental engineers. Since students, researchers and professors regularly interact in the context of courses, student projects and research programs, there are many valuable opportunities for creative solutions. The strategies that are presented below have been formulated within this special context.

Briefly, the Institute frames its research vision based on:

- A motivation driven by the global challenges that the world is facing
- A relative change of focus, from 'design and build' to 'maintain, operate and recycle'
- Multidisciplinarity and, in particular, an integration of research dimensions related to digitalization, automatization, optimization, additive manufacturing, uncertainty quantification, prolific computing, etc.
- A system-oriented approach, where not only the interactions among the components of complex civil systems are considered, but also the interactions of the system itself with natural and architectural environments

We will put increased emphasis on the development of computational resources, methods and metrics to address new issues. Recent technological and methodological developments provide new opportunities to address civil engineering challenges: robotics, artificial intelligence, data science, BIM, smart monitoring, large-scale optimization, numerical modeling, 3D printing, augmented humans, among others. These developments should be properly coupled with fundamental knowledge and civil engineering principles. This will guarantee a smooth cooperation that will result in solid improvements in the operations and maintenance of civil engineering facilities.

The IIC recruitment strategy has traditionally been triggered by retirements, with subsequent faculty searches inspired by profiles of retired professors. Although this makes a lot of sense in the short term, it is not ideal in anticipating and leading changes to the discipline. This is why we propose a proactive recruitment strategy that anticipates retirements, and identifies search profiles based on the general research vision of the Institute. To support this operationally, we have developed a methodology that enables simulation of the evolution of the Institute. Based on the rolling-horizon concept, the methodology accounts for two major ingredients:

- Design of a target Institute that is based solely on the vision, and not dependent on the current configuration
- A roadmap that investigates how to implement the target Institute in the long term, accounting for the current configuration of the Institute, and various important implementation constraints (budget, office space, experimental facilities)

The resulting roadmap will be a hiring plan for the next 10 (or more) years that anticipates the retirements of current professors, and suggests when new hires in each of the above-mentioned pillars should be done.

This roadmap will be used to justify each recruitment. But it is important that the roadmap is not engraved in stone. The idea of the rolling-horizon is that, for the next recruitment, the target Institute is potentially redesigned, and the hiring plan updated accordingly. Indeed, the strategy must be adjusted continuously to account for the rapid changes in research and in our society. Also, the constraints will evolve with time. The recruitment strategy will be both robust (thanks to the long-term anticipation) and flexible (thanks to the frequent updates). It will also help to better anticipate the resources needed.

The general strategy, in particular for faculty hiring, can be summarized as follows:

- Three research pillars representing the core of civil engineering, and plus two multi-disciplinary pillars oriented towards the other Institutes within ENACA balanced Institute, where each strategic research area has a critical mass
- A smooth, looking-forward, and regular hiring process
- A realignment of the teaching curriculum with the Institute's research priorities

5.4 Environmental Engineering Institute (IIE)

5.4.1 Overview

The Institute of Environmental Engineering is currently composed of the following laboratories (including joint professorships with other institutes of the ETH domain):

- APHYS – Physics of Aquatic Systems Laboratory – Prof. Alfred Johny Wüest (also with Eawag)
- APRL – Atmospheric Particle Research Laboratory – Prof. Satoshi Takahama
- CRYOS – Laboratory of Cryospheric Sciences – Prof. Michael Lehning (also with WSL)
- DISAL – Distributed Intelligent Systems and Algorithms Laboratory – Prof. Alcherio Martinoli
- ECHO – Laboratory of Ecohydrology – Prof. Andrea Rinaldo
- ECOL – Ecological Engineering Laboratory – Prof. D. Andrew Barry
- ECOS – Ecological Systems Laboratory – Prof. Alexandre Buttler (also with WSL)
- EML – Environmental Microbiology Laboratory – Prof. Rizlan Bernier-Latmani
- HERUS – Laboratory of Human-Environment Relations in Urban Systems – Prof. Claudia Binder
- LAPI – Laboratory of Atmospheric Processes and their Impacts – Prof. Athanasios Nenes
- LASIG – Geographic Information Systems Laboratory – Prof. Francois Golay
- LBE – Laboratory for Environmental Biotechnology – Prof. Christof Holliger
- LCE – Environmental Chemistry Laboratory – Prof. Tamar Kohn
- LGB – Laboratory for Biological Geochemistry – Prof. Anders Meibom
- LTE – Environmental Remote Sensing Laboratory – Prof. Alexis Berne
- LTQE – Laboratory for Water Quality and Treatment – Prof. Urs von Gunten (also with Eawag)
- SBER – Stream Biofilm and Ecosystem Research Laboratory – Prof. Tom Battin
- TOPO – Geodetic Engineering Laboratory – Prof. Bertrand Merminod
- TOX – Laboratory of Environmental Toxicology – Prof. Kristin Schirmer (also with Eawag)
- UPHCE – Prof. Hering Group in Environmental Chemistry – Prof. Janet Hering (Director Eawag)
- UPSSC – Prof. Steffen Group in Cryosphere Sciences – Prof. Konrad Steffen (Director WSL)
- WIRE – Wind Engineering and Renewable Energy Laboratory – Prof. Fernando Porte-Agel
- EPFL-PSI – Joint Professorship on Solid Waste Treatment – Prof. Christian Ludwig (also with PSI)
- GR-CEL- Central Environmental Laboratory – Dr. Florian Breider

The Institute hosts the following units:

- ECOTOX – Swiss Center for Applied Ecotoxicology EAWAG-EPFL – Dr. Benoit Ferrari
- The [WSL Site in Lausanne](#) of the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) – Prof. Alexandre Buttler (ECOS)

The following ENAC laboratory has a secondary affiliation with IIE:

- LMS – Soil Mechanics Laboratory – Prof. Lyesse Laloui

5.4.2 Personnel

Since 2011, 9 professors were hired and 5 professors and senior scientists (MER) have retired or left the institute. The faculty is currently composed of:

- 15 full professors
- 4 associate professors
- 1 assistant professor (tenure-track)
- 3 adjunct professors
- 1 senior scientist

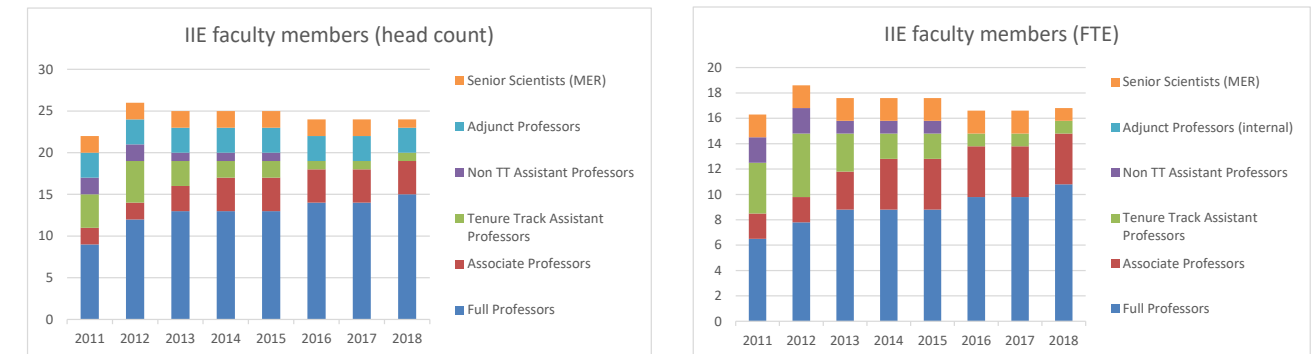


Figure 5.6. Evolution of IIE faculty members since 2011. (Left) Head count, including joint professorships with other Institutes of ETH domain. (Right) Full Time Equivalents (FTE), taking into account only activity rates at EPFL. TT = Tenure-Track, MER = Maître d'enseignement et de recherche.

5.4.3 Research Portfolio¹

The emphasis of IIE is on translational science based upon rigorous understanding of the environment, seamless integration of data and models, humans as integral parts of environmental systems, and development of novel, leading-edge technologies. The present era of rapid environmental change – the Anthropocene – and the resultant stressors are apparent in all aspects of our planet's functioning, and at all scales. Significant increases in atmospheric CO₂ concentrations above preindustrial levels and the consequent global warming are only one well-known change. Ongoing urbanization and the accompanying footprints due to food production, water supply, energy demand and mineral extraction directly affect the productivity and diversity of terrestrial, freshwater and oceanic ecosystems.

The scope of Environmental Engineering, with its goal of understanding, assessing and modifying environmental and human systems to achieve sustainable outcomes, is clearly broad. Natural systems can only be understood on the foundation of environmental sciences, and quantified using process-based mechanisms. By definition, the Anthropocene reflects long-term human-environment interactions and feedbacks, which are key aspects of creating practical solutions. Similarly, empirical data on environmental systems is vital for developing sustainable designs. Measurement technologies (from in situ instrumentation to satellites) are expanding rapidly, as is the availability of abundant data. Coupled with modeling, data availability provides new vistas in understanding and predicting environmental changes.

Research in the Institute of Environmental Engineering targets all the above elements:

- Basic environmental sciences
- Modeling and quantification
- Human-environment interactions
- Ubiquitous data and its use
- Technologies for sensing and data acquisition
- Technological solutions to human impacts

IIE's current research foci can be grouped into different domains, as described below.

¹ <https://www.epfl.ch/schools/enac/research/environmental-engineering-institute-iie/>

5.4.3.1 Atmosphere and Climate

The atmosphere plays a central role for the environmental conditions on earth. Yet, our understanding of the system 'atmosphere' is incomplete and predictions concerning the development of the climate and its effects/feedbacks on the environment are subject to large uncertainties. Therefore, one of IIE's objectives is to better understand the complex interactions between the atmosphere and other parts of the

earth system. An interdisciplinary and integrated approach is pursued, with laboratory studies, field measurement campaigns, and long-term observations of the atmosphere. All these aspects are combined with model simulations to enhance knowledge of earth-atmosphere interactions and their impacts on anthropogenic activities. To achieve these objectives, IIE concentrates on the following research activities:

- Land/atmosphere interactions – water fluxes, influence of land surfaces
- Development of innovative sensing technologies – robots, wireless networks, boundary-layer LIDAR
- Aerosol-cloud interactions, modeling and monitoring

5.4.3.2 Ecology and Biogeochemical Cycles

All chemical elements on Earth are cycled to various extents through biogeochemical cycles. All of these cycles include water (in liquid, solid or gaseous form), biomass and soil or sediments and many include an atmospheric component. The biological transformation of these elements is linked to the ecology of both microscopic and macroscopic life. A detailed understanding of these biogeochemical cycles

and their link to ecology is critical to tackling environmental change and the impact of anthropogenic activities on the planet, and to harnessing these processes for engineering applications such as waste treatment and remediation. IIE focuses on several aspects of biogeochemical cycling and ecology:

- Biogeochemical cycling in soils, inland waters and the ocean
- Trace element cycling in terrestrial environments
- Biogeochemical transformations for waste treatment and nutrient recovery
- Ecological impact of climate change and toxicants
- Modeling of biogeochemical transformations

5.4.3.3 Environmental Modeling and Monitoring

Environmental science and engineering is based on our ability to understand complex environmental phenomena that interact across a wide range of scales. In order to better understand these phenomena and their impacts, it is essential to understand and observe our environment in a broad sense. Indeed, its sustainable management requires utilization of a large amount of diverse data on soil, water and atmosphere, which must be integrated into complex decision-making processes. Modern technologies and state-of-the-art instru-

ments provide researchers with the ability to acquire, transfer and store large amounts of data, as well as powerful algorithms and software for simulating environmental systems. Dynamic sampling and regular updating of data allow for effective monitoring (surveillance) as well as improved prevention and better risk management. Several IIE laboratories carry out research in the field of monitoring and environmental modeling. Their main lines of research focus on:

- Sensor networks
- Environmental remote sensing and atmospheric variables
- Environmental genomics
- Decision support systems
- Atmospheric aerosols
- Snow, ice and permafrost
- Chemical pollutants, microplastics and pathogens in the aqueous environment

5.4.3.4 Human-Environment Interactions

Environmental engineers must understand how complex environmental phenomena interact with the human system. There are different kinds of human-environment interaction. First, the quality of environmental system affects the social system, e.g., pollution of air, water and soil affects human health and well-being. Second, human activities, in particular land-use change, affect the environmental system or ecosystem services. It is thus essential to analyze, model and assess the effect of human activities on resource use and

environmental pollution and determine the factors driving human behavior. Third, there is reciprocity between the human and the environmental systems, including feedback loops. These different categories of interaction are understood by integrating both environmental and social dynamics in conceptual and simulation models and data requirements. In particular, the use of big data and new digitalization tools will strongly drive research into human-environment interactions in the future.

IIE covers both basic and applied research in human-environment interactions, including:

- Sustainable environmental management based on integration of soil, water and atmospheric data into complex decision-making processes
- Software tools for simulation of environmental systems, leading to relevant outcomes such as improved early warning and risk management
- Concurrent and interactive adaptations of human social systems and ecosystem functioning
- Identification of social characteristics that control human impacts on ecosystems and actions that can affect those impacts
- Characterizing concepts underlying interactions between the social and ecological systems
- Health impacts of atmospheric aerosols

5.4.3.5 Water and Waste Engineering

A major goal of environmental engineers is the maintenance of high quality water, soil and air. These essential environmental resources are increasingly impacted by a multitude of contaminants of anthropogenic origin. A detailed and thorough understanding of the biological, chemical, and physical processes affecting the fate of contaminants in natural and engineered systems is required in order to find solutions that

minimize their deleterious environmental impact. This knowledge also facilitates the planning, design, and operation of engineered facilities that ensure the quality of natural environments. IIE concentrates its efforts on the quantification of processes and the elucidation of their mechanisms.

The processes of interest relate to

- Pollutant transformation and transport in natural and engineered systems
- Remediation of contaminated sites
- Development of novel processes for the treatment of water, wastewater, and solid waste

5.4.3.6 ALPOLE – Alpine and Polar Research

EPFL, with support of the Canton of Valais, is creating the new ALPOLE research center as part of an expansion of the EPFL Sion campus. ALPOLE is part of the Institute of Environmental Engineering (IIE), and will substantially expand the Institute's research and teaching programs. The establishment of ALPOLE recognizes the global relevance of changes taking place in high-altitude and high-latitude environments, which are sentinels of climate change. The cascading effects

are evident in agriculture, tourism, infrastructure planning and landscape management. A major challenge is, and will be, the understanding and prediction of climate-induced impacts on the environment, as well as adaptations to these impacts.

ALPOLE, which will be located in a dedicated building at Sion (completed in 2022), is built around 5 new professorships:

- Extreme Environments (search underway)
- Computational Environmental Science and Engineering (search underway)
- Catchment Science and Engineering (search in 2020)
- Environmental Adaptation (search in 2020)
- Stream Biofilms and Ecosystems (Prof. T. Battin, [SBER](#))

Several research groups from cognate scientific disciplines within ENAC will be co-located with ALPOLE at Sion, as will the Swiss Polar Institute (section 2.5.3.6), creating a large

(up to 150 people) and synergistic research effort on climate-driven environmental changes and adaptations.

5.4.4 Vision

Environmental Engineering is a rapidly evolving and inherently interdisciplinary field, which necessarily embraces the ever-growing footprint of humanity on the environment. As an Institute addressing major environmental concerns, IIE's strategy is to anticipate and lead in selected research directions, at the same time recognizing present day issues, as captured in the following tenets:

- Promote system-level thinking, i.e., thinking across scales, to understand environmental problems and their impacts from the local to the global scale
- Encourage multidisciplinary work (across natural and social sciences, and across the natural and built environments), which are essential for addressing complex, interconnected problems related to environmental change
- Integrate the rapidly developing opportunities related to big environmental data and data science into IIE's research activities
- Make sustainability and impact assessment a priority

Mindful of these principles, IIE has identified four core research foci around which the Institute will be positioned over the next decade. These four foci leverage the current strengths of IIE's faculty, and will be augmented by upcoming hires. IIE's four research foci are:

- *Polar and Alpine Environments in a Changing Climate* – Global change in general, and climate change in particular, are rapidly altering our environment. Polar and alpine environments are particularly affected, with currently unknown consequences for their ecosystems and climate. Human quality of life depends on alpine environments (particularly in Switzerland), which are extensively utilized for housing, recreation, creation of revenue and hydropower production. IIE will use a comprehensive, system-oriented approach to determine the impacts of environmental change on biogeochemical cycles and natural hazards in mountainous regions, and to rigorously characterize adaptation to extreme environments affected by climate change. Necessarily, this includes connecting the hydrology of extreme environments to biogeochemical cycles and ecological changes/adaptation. With the establishment of ALPOLE (section 5.3.4.6) and its anticipated close relationship with the Swiss Polar Institute (section 2.5.3.6), the existing strengths in alpine and polar research within IIE, and the proximity of EPFL to the Alps, IIE will have the opportunity to become a world leader in understanding polar and alpine environments.

- *Ecosystem and Human Health* – Also related to global change, a past, current and future core challenge for environmental engineers is to maintain or restore the quality of natural resources. This challenge will magnify over the coming decades as the growing world population and the accompanying urbanization intensifies pressure on limited resources (e.g., water, agricultural soil). Concomitantly, rising consumption and insufficient consideration of waste will cause higher levels of pollution (e.g., oceanic plastic pollution). Environmental engineers are therefore called on to develop strategies for sustainable resource management. Traditionally, this has included technical solutions and environmental monitoring, and these aspects will continue to be relevant. In addition, however, IIE will also evaluate the effects of resource quality on ecosystem and human health, and to develop metrics to assess resource quality and effects of changes. This necessitates a highly interdisciplinary, system-level approach, the achievement of which will influence the future faculty composition of IIE.

- *Distributed Environmental Observation and Interpretation* – IIE currently encompasses both environmental simulation and the development of cutting-edge, smart technologies. As such, this puts the Institute at the technological forefront with respect to environmental data collection and interpretation. In line with EPFL's research priorities, IIE plans to expand its technology development capacity and become a center for distributed environmental observation and interpretation. By housing both developers and modelers in the same Institute, it will be possible to develop unique technological and simulation tools specific to environmental processes together with data acquisition strategies designed to address environmental problems. Through big environmental data, IIE's goal is to use data-driven science to anticipate environmental risks and monitor impacts, from local and global scales. This research focus has obvious links to other Institutes within and outside ENAC (e.g., civil engineering, robotics, mechatronics, [Swiss Data Science Center](#)).

- *Human-Environment Interactions* – An emerging area of environmental engineering is the analysis, quantification and assessment of human-environment interactions. Human systems are closely interlinked with the environment. For example, ecosystems provide essential services (e.g., agricultural land) to humans, and humans consume resources (e.g., energy). The demand for resources and use of ecosystem services impacts the environment (e.g., via building cities). Determining how the environment and humans are linked and how they co-evolve can inform policies for sustainable human activities. As such, this relatively new aspect of environmental engineering is an intriguing and highly relevant link between science and engineering into policy making. Expertise in human-environment interactions already exists within the Institute, but will be further strengthened in the future (cf. Ecosystem and Human Health above). The research focus will benefit from the proximity to the other two ENAC Institutes (e.g., urban sciences, sustainable technologies, smart living, environmental and urban economics) as well as the digital humanities (College of Humanities).

Institute Structure

To successfully navigate the complexity of these four research areas, IIE will tackle environmental problems from different angles. Specifically, three methodological poles will be built indicated by the corners of the triangle shown in Figure 5.7 (different laboratories may have research activities in different poles). The first two, *field and lab experiments* and *environmental modeling and simulation* are tried and tested tools of environmental engineering that are strengths of IIE. The third pole, *impact assessment* refers to novel approaches to anticipate risks and assess the imprint of environmental change on ecosystems and humans.

These methodological poles span different outcomes relevant to environmental engineering, indicated by the triangle's axes: the generation of knowledge of environmental processes, the management and interpretation of environmental data, and the development of sustainable engineering solutions.

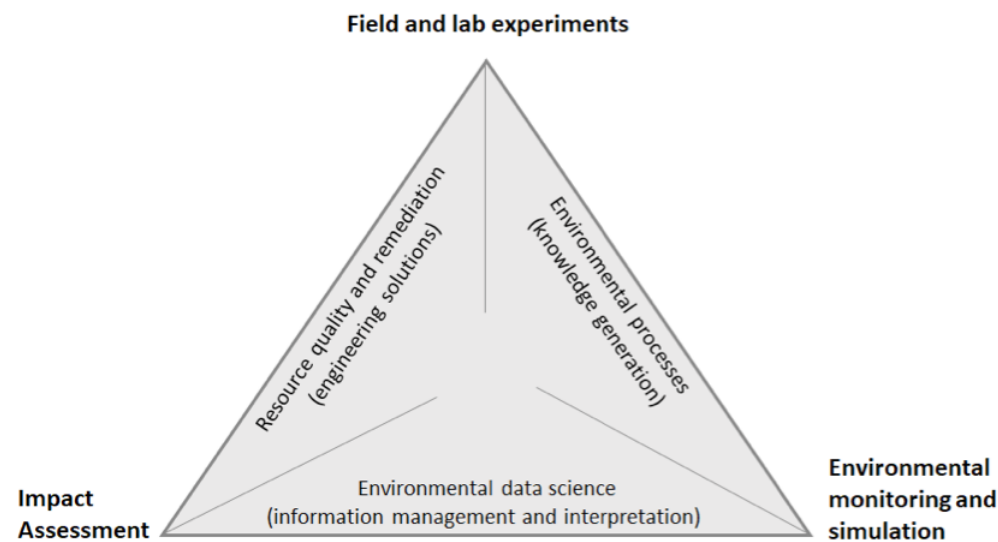


Figure 5.7. Schematic of IIE's methodological poles (corners of the triangle) and the different scientific and engineering domains supported by them (interior of the triangle).

A simplified overview of the research foci of IIE laboratories, combined with their methodological approaches, is given in Table 5.1. The Institute's aim is to build critical mass based on the matrix structure in this table. Table 5.1 includes present faculty that will be present in IIE in 2024 and beyond, as well as ongoing faculty searches. IIE is already well-positioned to tackle a subset of the research challenges described above. Critical gaps remain, for instance in the area of impact assessment, that will guide future faculty hires.

Table 5.1. Overview of positioning of IIE laboratories at present. Existing laboratories are represented as solid circles (one laboratory per circle) and planned laboratories by unfilled circles.

	Impact Assessment	Field and lab experiments	Simulation and monitoring
Alpine environments	○	● ○ ○	● ● ● ○ ○
Distributed observation and interpretation	●	○	● ● ● ● ● ○
Resource quality and its effects on ecosystem health	● ● ○	● ● ● ● ○	● ● ● ○
Human-environment interactions	● ● ●	●	● ● ●

5.4.5 Scientific Output and Scholarly Impact

The scientific output of IIE has steadily increased over the past decade. Note that the number of faculty has been essentially constant (actually, slightly decreasing) since the last audit (Figure 5.6). Since 2008, the total number of Web of Science (WoS) publications in IIE has tripled and is now stable at approximately 160 publications per year (Figure 5.8). Overall, these publications were cited close to 28,000 times, resulting in a Category Normalized Citation Impact (CNCI) of 1.92. The CNCI of the individual subject areas covered by IIE are shown in Figure 5.8, revealing an impact well above average for all subject categories.

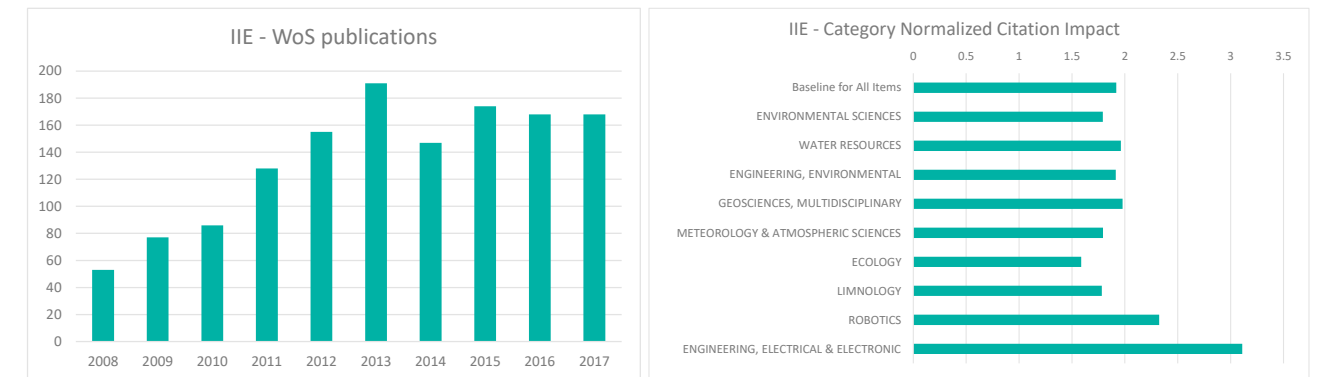


Figure 5.8. (left) Number of publications authored by IIE faculty (professors and MERs) indexed in Web of Science. Only publications attributed to EPFL are considered (InCites data exported 22 February 2019). (right) Category Normalized Citation Impact for IIE publications authored from 2008-2017 (2018 not available), according to subject category.

According to Infoscience (EPFL's research repository), IIE has steadily increased its scientific production since 2008. This increase is mainly due to growth in the number of published journal articles. Infoscience lists a total of 3438 documents deposited from 2008-2018, of which journal articles constitute 75% (Figure 5.9).



Figure 5.9. (left) IIE publications in Infoscience (no filters applied). The category "Journal articles" includes both original research papers and reviews. (right) Spider plot of the type of publications produced by IIE from 2008-2018.

5.4.6 Inter- and Multidisciplinary Collaboration

Environmental Engineering is an inherently interdisciplinary field. This is reflected in the diverse backgrounds and current activities of the IIE faculty, which consists of environmental engineers, chemical engineers, mathematicians, physicists, chemists, biologists, mechanical engineers and electrical engineers. Consequently, we collaborate extensively with disciplinary Institutes all other faculties at EPFL and elsewhere, as well as with the other ENAC Institutes. Finally,

Red Sea Transnational Research Center

The Laboratory of Biological Geochemistry ([LGB](#)), working in close collaboration with Israeli and Saudi Arabian coral biologists/physiologists, recently discovered that the coral reefs in the Gulf of Aqaba (and the Northern Red Sea in general) are exceptionally resistant to global warming, the effects of which are in the process of killing off most other major reef systems in our oceans. This work has led to an international effort, supported by the Swiss Foreign Ministry, to establish a *Red Sea Transnational Research Center* led by EPFL. Scientifically, the intention with this Center is that it will serve as the engine for broad, regional-scale collaborations to monitor and protect the unique Red Sea coral reef ecosystems through state-of-the-art research into their health and biodiversity, and create an international platform for collaborative research on the environmental impact of socio-economic

the nature of our work leads to natural collaborations with the ETH research Institutes with activities in the environmental domain, namely, Eawag (including two joint professorships), WSL (including two joint professorships) and Empa. Examples of existing and planned interdisciplinary activities of three laboratories are given below, to illustrate the diversity of inter- and multidisciplinary activities at IIE. Numerous other examples could be provided.

developments along the shores of the Red Sea; e.g., agriculture, urbanization, coastal infrastructure, fishing, and industrialization. The broad and highly interdisciplinary research effort organized by the planned Center will provide policy- and lawmakers in the region with cutting-edge scientific analyses for decision-making with regard to environmental protection strategies. Furthermore, the Research Center will be directly connected to high level diplomatic representatives from regional powers (including Egypt, Jordan, Saudi Arabia, and Israel) and thus use science and the common interest in the preservation of the unique Red Sea coral reefs as a mechanism to build bridges between these nations, and therefore become a prime example of Science for Diplomacy and Diplomacy for Science.

River Networks as Ecological Corridors

The Laboratory of Ecohydrology ([ECHO](#)) deals with investigations on how the physical structure of the environment affects biodiversity, species invasions, survival and extinction, and endemic or epidemic waterborne disease infection spreads. In this context, ECHO has recently pursued numerous interdisciplinary studies on:

- Spread of proliferative kidney disease in salmonid fish in a Swiss prealpine catchment, a project comprising field, laboratory and theoretical studies carried out in collaboration with fish biologists and veterinary science researchers (University of Bern) and molecular biologists (Eawag)
- Estimation of species distribution and abundance in river networks using environmental DNA, in collaboration with molecular biologists (Eawag)
- Biological invasions of model species (protists, bacteria) within heterogeneous ecological corridors, carried out in collaboration with experimental ecologists (Eawag, University of Zürich), and experts in microfluidics (ETHZ)
- Fluvial network imprints on microbial co-occurrence networks, in collaboration with stream ecologists (EPFL, Leibniz I Berlin, Universities of Glasgow and Vienna)
- Spread of schistosomiasis (an endemic macroparasitic waterborne disease) in Burkina Faso as a result of water resources development, carried out in collaboration with field ecologists (Zie Ouagadougou, Stanford University), epidemiologists (Swiss Tropical and Public Health Institute) and theoretical ecologists (Politecnico di Milano)
- Spread of epidemic cholera in Kwa-Zulu Natal, Haiti, Senegal and South Sudan, in collaboration with environmental microbiologists (EPFL), epidemiologists (Pan American Health Organization, Harvard University, Johns Hopkins University, Université Assane Seck Ziguinchor, University of Montpellier, World Health Organization South Sudan), statistical physicists (University of Padova), ecohydrologists (Princeton University) and telecommunication experts tracking human mobility fluxes via mobile phones (Politecnico di Milano)

Urban Gardening and Human Well-Being

This project, carried out by the Laboratory for Human Environment Relations in Urban Systems ([HERUS](#)), focused on an integrated assessment of urban agriculture. The project was carried in collaboration with the five ENAC research groups that combined expertise in transition studies, ecology, biotechnology, toxicology and urban planning. The project aimed at understanding urban agriculture from an inter- and transdisciplinary perspectives to determine to what extent urban agriculture in Switzerland can contribute to human well-being and sustainable urban food systems. Relevant issues that emerged out of the project concentrated into four distinct research perspectives, viz.,

- Urban agriculture issues related to natural sciences, e.g., how to improve biodiversity and preserve soil quality?

- Urban agriculture issues related to new technologies and innovation, e.g., what are the roles of new technologies and innovation in urban agriculture?
- Urban agriculture issues related to human well-being and education, e.g., how to improve citizen's social relations and environmental education through urban gardening
- Urban agriculture issues related to urban planning and policies, e.g., how to improve land accessibility and which roles for city or state policies?

The results were discussed with academics and practitioners in a full-day workshop in April 2017, leading to a number of specific suggestions for further research and possible policy interventions.

5.4.7 Outlook and Perspectives

The establishment of ALPOLE, along with the faculty turnover over the next 5-7 years will bring profound changes and opportunities to IIE. It will allow the Institute to regroup its research activities under the umbrella of the topics outlined in the research vision, and to reach critical mass in designated areas (Table 5.1). This structure will create an inclusive IIE designed to foster collaboration among faculty members.

The next decade will also bring a shift in the approaches that we use. Modern environmental engineering goes well beyond the essential solid foundation in science and engineering, and must also include the ability to think across scales and

disciplines (system-level thinking), a savviness with new technologies (e.g., smart sensors, field robotics) and digital tools for improved environmental monitoring strategies, and an appreciation of the human factor in shaping environmental decisions and actions. IIE's identified methodological poles will be strengthened, and we will actively seek to make these abilities part of our faculty profile. The Institute will continue to collaborate extensively, forming research partnerships with the other ENAC Institutes and external organizations.

Finally, the upcoming hiring opportunities will furthermore allow the Institute to rectify the age and gender distribution of its faculty, with an emphasis on attracting young, female faculty.

5.5 Shared Scientific Infrastructure

ENAC's policy is to provide major facilities as platforms, which are available to the ENAC community and beyond. This policy follows the EPFL strategy of concentrating general-use facilities into dedicated platforms. Major ENAC [platforms](#):

- X-Ray Radioscopy and Tomography Platform
- Atelier des Maquettes
- Civil engineering large-scale testing facilities
- Experimental building for the Solar Energy and Building Physics Laboratory
- Central Environmental Laboratory
- ENAC Technical Platform
- Archives of Modern Construction
- Atelier Pop^{UP}
- Hydraulic Constructions Platform

Descriptions of some of the larger facilities follow.

5.5.1 ENAC Interdisciplinary Platform for X-ray Micro-tomography (PIXE)

[PIXE](#) is a central ENAC facility in X-ray micro CT dedicated to engineering studies of materials. It hosts a state-of-the-art dual-source micro CT system, and dedicated, experienced staff who lead research and development activities in the field of 3D structural imaging of materials. Its very high resolution micro CT system is especially designed for engineering experiments and for the future implementation of coupled in situ testing facilities (e.g., loading, thermal and permeability tests).

- Non-destructive investigation of the microstructure of materials
- Monitoring dynamic microstructural processes
- Establishment of quality control on pre-existing microstructures that may influence the behavior of the tested materials
- Provision of structural models to simulate the behavior of complex materials

Description – The PIXE platform includes an RX-Solutions Ultratom micro-CT system with two X-ray generators. A 230 kV generator provides high-resolution analyses (voxel size up to 5 microns) on relatively large samples (cm to dm) and a 160 kV tube for ultra-high resolution analyses (voxel size up to 0.5 microns) on very small samples (mm to cm). This micro CT system is completed by two graphical stations for image analysis, a DB-5000RT Debens' tensile and compression testing system (5 KN) for in situ monitoring experiments and a Neotim thermal conductivimeter.

Mission – PIXE's mission is primarily to support ENAC researchers and the broader EPFL community to observe and determine the 3D microstructure of natural and engineered materials when these are subjected to changes such as loading, thermal or saturation variation, corrosion, dissolution or biological decay. More precisely, PIXE opens up new avenues for research through the possibilities for:

Users and Projects – The platform supports ENAC students and researchers, as well as other EPFL units (e.g., mechanical, materials and bio-engineering). The facility can also be accessed by external scientific institutions to develop specific setups and perform tests on structural materials for gaining high-quality experimental data for engineering and scientific research, teaching and technology transfer. The PIXE core partners' group comprises six research units that integrate micro CT in their research. In the past year, numerous other groups have used PIXE, viz. 33 EPFL laboratories, 8 research laboratories outside EPFL and 7 private enterprises.

Outlook – PIXE is still in its initial phase, having begun operations in 2017. It focuses on four main axes:

- Improving research by integrating micro CT analyses into project pre-design
- Expanding in situ test systems (in particular specific loading cells and isothermal cells)
- Intensifying national and international collaborations
- Sharing PIXE's tomographic database and post-processing routines to the scientific community (open science project)

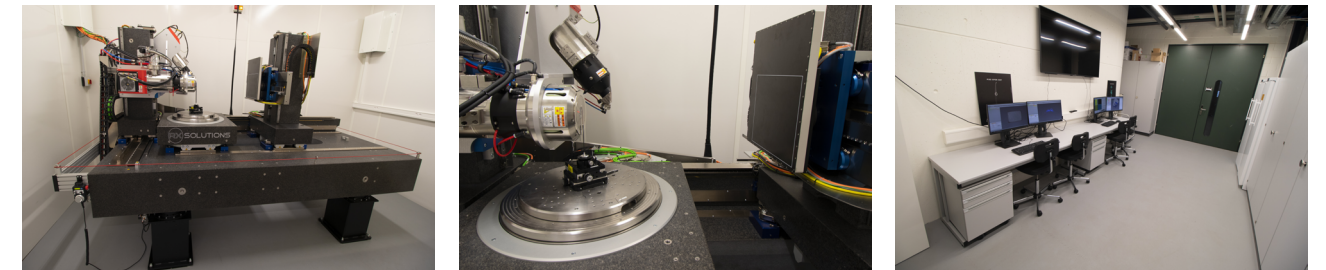


Figure 5.10. (left to right) The micro CT Ultratom system / X-ray generators / Graphical stations for image analysis.

Example PIXE research projects



Figure 5.11. Fauzia Albertin (EPFL LQM) analyzed the writing of a [sealed testament](#) from the State Archives of Venice using different approaches including Micro CT (PIXE) – without breaking the wax seal – and revealed the last wishes of a Venetian woman from the year 1351.

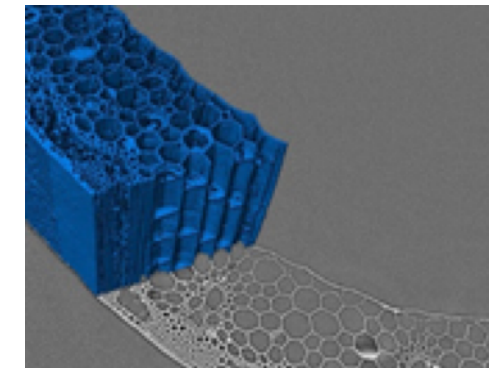


Figure 5.12. 3D microstructure of a rye stem (*Triticale secale*), part of an ongoing ENAC project (Prof. A. Buttler, Drs. Vassilopoulos and Turberg).

5.5.2 Central Environmental Laboratory of the Institute of Environmental Engineering (GR-CEL)

Mission – The overall mission of the Central Environmental Laboratory (GR-CEL) of the Institute of Environmental Engineering (IIE) is to assemble, operate and manage an array of cutting-edge analytical equipment, services, and know-how in support of high-level research relating to the understanding of pollutants and micro-organisms, their behavior in the environment, and the characterization of water, soil, sediment, and air quality and composition. This includes the establishment of common top-quality equipment related to water, soil, air and biological analysis. GR-CEL acts as an exchange of know-how and competence in environmental analytical chemistry and molecular biology among IIE, ENAC and other EPFL laboratories. It is also involved in the teaching activities of the Section of Environmental Sciences and Engineering (SSIE) through courses, design and Master projects. GR-CEL additionally offers opportunities for promoting collaboration with other ENAC and EPFL units sharing complementary research and educational interests. Finally, GR-CEL conducts its own research projects in the fields of environmental chemistry and molecular biology. Its research projects of GR-CEL mainly focus on the detection and the fate of organic and inorganic micro-pollutants in aquatic and terrestrial environments, the study of micro-plastic pollution and the study of microbial communities and antibiotic resistant bacteria in various environmental compartments.

Description – GR-CEL is equipped with a wide range of cutting-edge analytical instruments to characterize and quantify various organic and inorganic compounds in environmental samples such as water, soils, sediments and in natural and synthetic materials. The main instruments are: HPLC, ion chromatography, GC-MS, GC-MS/MS, LC-MS/MS, ICP-OES, LC-ICP-QQQ, HR-ICP-MS and different spectrometers (UV-vis, fluorescence, FT-IR). The expertise of GR-CEL covers the analysis of organic and inorganic pollutants such as pesticides, herbicides, pharmaceuticals, PCBs, PAHs, N-nitrosamines, heavy metals, trace elements, etc. GR-CEL is also equipped with devices needed for the sample collection, preparation and storage. Its equipment includes up-to-date microbiology and molecular biology devices such as microscopes, Q-PCR cyclers and a capillary sequencer for the characterization of microbial communities and functions.

Users – The GR-CEL supports scientists, post-doctoral fellows, PhD and Master students of EPFL and other research institutions for their research projects involving chemical and biological analytical techniques. The facilities are open to the whole scientific community with priority given to IIE and ENAC. About 85% of analysis carried out within GR-CEL are for IIE research groups whereas the remaining 15% are for scientists from other EPFL institutes (e.g., ISIC, IMX) and

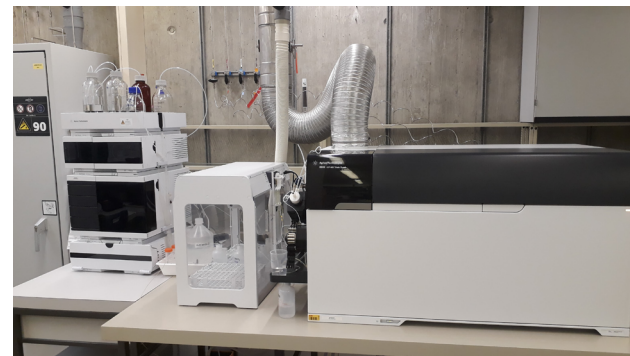


Figure 5.13. Liquid chromatography triple quadrupole inductively coupled plasma mass spectrometer (LC-ICP-QQQ) used for the analysis of trace elements in various samples.



Figure 5.14. Liquid chromatography tandem mass spectrometer (LC-MS/MS) used for the analysis of various organic compounds.

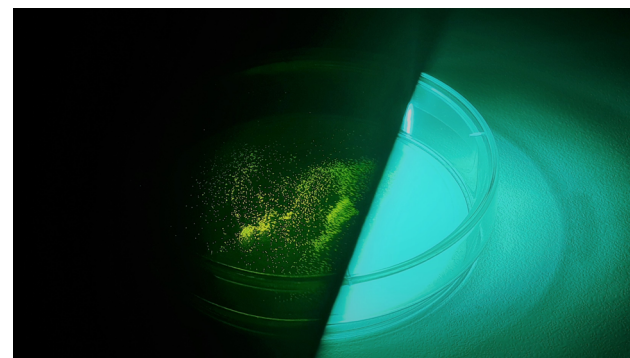


Figure 5.15. Microplastics under a fluorescence microscope.

other Swiss and foreign research institutions (e.g., UNIL, UNIGE, URCA, UFC).

Outlook – GR-CEL plans to reinforce the automation of routine chemical analyses by the acquisition of a fully automated high throughput spectrophotometric analyzer. This instrument will be mainly used for routine analysis of various ions in water, soil and sediment samples. The acquisition of this instrument will improve the analytical capacity of the laboratory. Its analytical capacity in the field of microplastics research will be also strengthened by the acquisition of a focal plane array infrared imaging system. This instrument will enable quantification and characterization of micro-plastic particles in different environmental samples. It will also be used by other research groups working in the fields of biogeochemistry, atmospheric sciences, environmental microbiology, palaeontology and biophysics. GR-CEL will also reinforce its involvement in research on micro-plastic pollution by strengthening its national and international collaborations with research laboratories, NGOs, federal and cantonal agencies and by the coordination of a citizen science project and the development of an open data repository (i.e., O-MAP project within the EPFL Open Science Fund). In the medium term, GR-CEL also intends to develop its scientific equipment in the fields of high resolution mass spectrometry and molecular imaging mass spectrometry. These techniques will strengthen research efforts of different IIE laboratories in the fields of the biogeochemistry, environmental chemistry and biology.

Research Highlights – In 2018, GR-CEL has contributed to numerous research projects and publications in the field of environmental chemistry, biogeochemistry, water treatment, microbiology and material science. For instance, the analytical and the molecular biology platforms of GR-CEL improved understanding of the role of alkyl quaternary ammonium compounds in the formation of carcinogenic N-nitrosamines in aquatic systems; helped identify microbial communities associated with uranium in situ recovery mining processes; produced new insights into bacterial arsenic bio-methylation and bio-volatilization pathways and determined the importance of micro-plastic fluxes in Lake Geneva.

5.5.3 Structural Engineering Platform of the Civil Engineering Institute (GIS Laboratory)



Mission – Experimental structural engineering research provides the opportunity to observe the unknown, to develop the new, and to challenge existing numerical and mechanical models. The mission of the Structural Engineering Platform (GIS) of the Civil Engineering Institute is to support researchers to understand the response of selected parts of structures when subjected to extreme loadings, extend the service duration of existing structures by detecting their effective capacity and to develop new structural materials and systems that support the vision of a sustainable, more resilient future for all societies. To reach this goal, the Structural Engineering Platform offers a wide range of experimental facilities for testing structural materials and components at various scales and under a large range of loadings (static and dynamic forces and displacements, temperature). It supports PhD students, post-doctoral fellows as well as Master and Bachelor students in developing unique test setups and

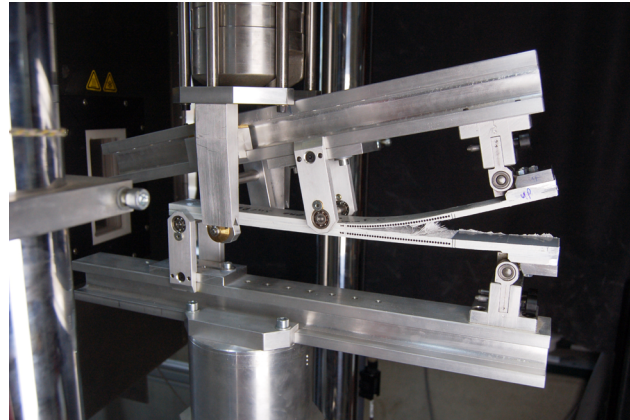
performing tests on structural materials and components for gaining high-quality experimental data for structural engineering research, teaching and technology transfer. Next to research data, the experience of conducting large-scale experimental tests provides each researcher with the unique opportunity to observe the controlled failure of structural components and to gain a feeling and intuition for their structural behavior. Through interactive visits for the public in general and school classes in particular, the Structural Engineering Platform makes the impact of its research on the quality of life tangible to all.

Description – The GIS laboratory comprises four testing halls, four climatic rooms as well as three workshops. The heart of the GIS laboratory is the strong floor, on which a Meccano-type steel system allows the construction of project-specific test setups. Several sets of servo-controlled ac-

tuators are used to apply force- and displacement-controlled boundary conditions; a particular feature of the laboratory is its capacities for carrying out low and high cycle fatigue tests. It offers a wide range of optical measurement systems, suitable for measuring 3D displacement fields of specimens of all scales. A large set of universal testing machines are available for material and component testing under uniaxial and multiaxial loading as well as combined mechanical-temperature loading. The workshops allow producing unique testing and measuring equipment as well as test units. Technical support is provided by two engineers and five technicians.

Users – The main users of the GIS laboratory are PhD and postdoctoral students of the seven structural engineering research groups that perform experimental research. Master and Bachelor students profit from these facilities in particular during various ENAC Week projects and ENAC Teaching Units as well as semester and Master projects. Every year, many visitors participate in activities and guided tours (2018: 165).

Outlook – The platform will reinforce image-based data acquisition methods as a basis for data-driven engineering techniques and input for model validation across scales, along with system for post-processing and sharing data



openly. One testing hall will be dedicated to automation and mimic processes of a construction site of the future. Future capacity developments will reinforce the current strengths of the laboratory with regard to low and high cycle fatigue testing as well as testing of materials under multi-axial loading and combined temperature-mechanical loading. A recently completed test rig (Cage) will allow the control of up to 8 channels and introduce hybrid simulation to the laboratory (interactive testing of part of a structure while simulating its overall behavior).

5.5.4 Platform of Hydraulic Constructions of the Civil Engineering Institute (PL-LCH)

Mission – The Platform of Hydraulic Constructions (PL-LCH) aims to maintain and reinforce the long Swiss tradition of international excellence in the field of water resources management and hydraulic engineering. This entails:

- Teaching future civil engineers wishing to specialize in hydraulic structure systems
- Carrying out research at an international level
- Transferring its experience to engineering practice

PL-LCH thus maintains synergy between teaching, research and technology transfer. Its research concentrates on the interactions of hydraulic structures and schemes with the environment, with an emphasis on topics corresponding to present and future concerns of large infrastructure projects for use of water and protection against water. Research is carried out by using hybrid approach of physical models and numerical simulations.

Description – The hydraulic laboratory covers two floors with a total area of 1,775 m². The water supply of the channels and models comes from an 800 m³ main reservoir, through nine pumps and independent hydraulic circuits. A 100 m³ tank is available for experiments using suspended sediment, colorants or other material. A volumetric measurement basin

allows calibration of electromagnetic flow meters mounted on the circuits. A series of constant or adjustable transparent flumes completes the platform's fixed equipment. A computer monitors the operation of each circuit and executes requests made on mobile control desks. Each circuit can also be piloted from the control room where information for regulation is gathered.

Users and Projects – PL-LCH has an active research profile based on third-party funding (CHF9.5 mio during 2011-2018 for research projects and CHF1.9 mio for technology transfer projects). In 2018, the platform hosted 9 PhD students, 7 post-doctoral fellows, 11 Master and 1 Bachelor thesis students. Master and Bachelor students, coming from both civil and environmental engineering, benefited from these facilities in particular during various semester ENAC projects.

Outlook – The hydraulics laboratory is active in research, training and the promotion of its scientific activities. Since the 1930s, it has been offering its services to the local, Swiss and international community in the field of applied hydraulic engineering through physical modeling and for about 25 years also through numerical simulation. Research in the general hydraulic thematic (river flow, pressure flow, hydro-

power, environmental hydraulics, special hydraulic works) were continuously performed at the hydraulics laboratory and will go on, including research defined together with federal authorities (Federal Offices for the Environment as well as for Energy), InnoSuisse grants, as well as international collaboration (Japan, Ireland, Canada, Brazil, etc.). In parallel, the PL-LCH is very active in teaching and training, offering one Bachelor and four Master level courses as well as Master thesis and several semester projects.



Figure 5.16. Curved channel (25 m x 1 m) and channel with variable slope (43 m x 2 m).

Example projects

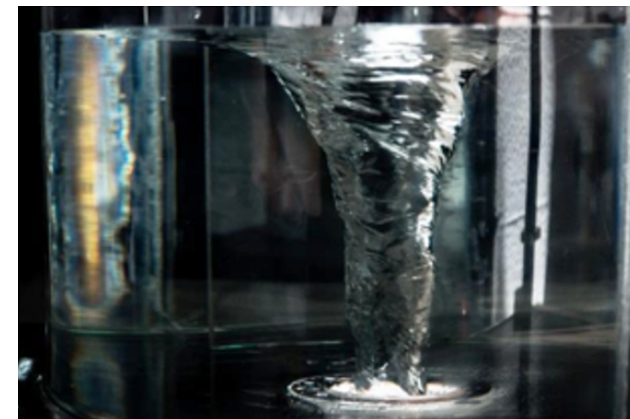


Figure 5.17. Free surface vortex flow, experiments and SPH numerical modeling (CEVA Geneva urban rail link project).



Figure 5.18. Ecological restoration of rivers with a focus on improvement of ecosystem services, based on large scale experiments and process-based modeling.

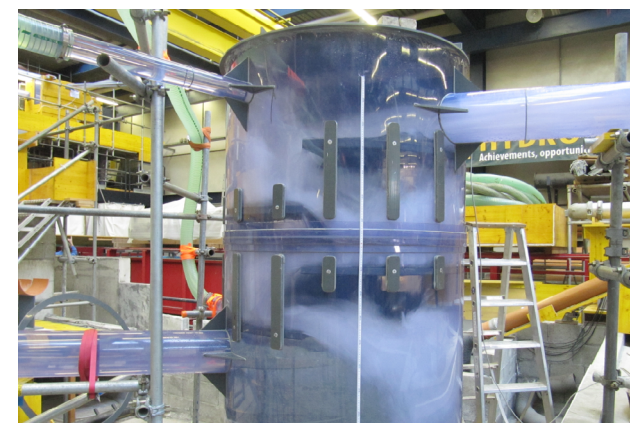


Figure 5.19. Drop-shaft structures in urban hydraulics.

6. Innovation, Technology Transfer and Public Outreach

6.1 Overview

Along with education and research, innovation and technology transfer is the third core mission of EPFL. EPFL as a whole performs well in innovation and technology transfer – in 2018, EPFL was ranked #4 in the [Reuters Top 100: Europe's Most Innovative Universities](#). Many research results from ENAC are used outside the academic world. Successful implementation is challenging and often political because many innovations developed by ENAC laboratories touch on broad societal questions and need to reach a variety of actors from industry and public agencies for successful implementation. While the challenges are important, the impact on quality of life is far-reaching. The technology transfer and implementation of ENAC research outputs is therefore as multi-faceted as ENAC's research. Counting patents and start-up companies alone is insufficient. This Chapter describes the ecosystem for innovation and technology transfer that was created at EPFL and at ENAC specifically. It highlights particular programs that were put in place at ENAC since the last Audit to support innovation and technology transfer, and to foster in particular an entrepreneurial spirit and creativity among its members.

6.2 EPFL Support for Technology Transfer and Innovation

6.2.1 Vice Presidency of Innovation and Technology Transfer Office

At the EPFL level, the Vice Presidency of Innovation (VPI) and the Technology Transfer Office (TTO) provide support to researchers for technology transfer and innovation.

Vice Presidency of Innovation – VPI's mission is to encourage entrepreneurship at all levels, to help industry develop broader partnerships with EPFL, and to foster innovation. The VPI is also responsible for operating the EPFL Innovation Park, which was established in 1993 on the Lausanne campus, and has since become a central hub for the entire Lake Geneva region to engage with EPFL. Of the companies that have offices at the [EPFL Innovation Park](#), ENAC laboratories collaborate in particular with Logitech, Romande Energie, Swiss Rail, Schindler, Swisscom, PSA and Pix4D. The VPI is also in charge of the Swiss Innovation [Park Network West EPFL](#), a joint venture between EPFL and the Cantons of Fribourg, Geneva, Neuchâtel, Vaud and Valais, which provides global visibility for innovation parks at all EPFL campuses.

The VPI promotes entrepreneurship at EPFL through its [Innogrants program](#), which was launched in 2005. Since the start of this program, more than 100 entrepreneurial projects have been supported (~CHF 100 k per project, 12 months duration). Thirty Innogrant applications (4%) originated in ENAC but only two of these were funded. These low rates of applications and grants obtained motivated the creation of the InnoSeed ENAC Program (section 6.3.1).

Technology Transfer Office – The mission of the EPFL Technology Transfer Office (TTO) is to negotiate contracts with industrial partners, manage EPFL intellectual property, encourage and provide support to laboratories in patenting activities, and lastly, to manage licensing of EPFL technologies. Although the TTO is part of the Vice Presidency for Research (VPR), strong links exist between the VPI and the TTO, who share offices in the EPFL Innovation Park and work in close collaboration. The TTO supports technology transfer through its [Enable Program](#), which was established in 2010 and supports researchers who intend to develop their inventions further in order to demonstrate their potential. The project grants from the Enable Program are generally for short-term projects (~CHF30k per project, six months duration).

6.2.2 Transportation Center (TRACE)

The Transportation Center ([TRACE](#)) is an EPFL strategic research center launched in 2009, and has particular relevance for ENAC in terms of innovation and technology transfer. TRACE acts as the interface between EPFL and the outside world for all matters related to transportation and mobility, of both people and goods. In this regard, the main objectives of TRACE are to:

- Initiate transportation-related research projects in collaboration with private and public partners
- Build strong partnerships with key players in the transportation sector at national and international levels
- Raise external funding to support the development and the expansion of transportation research at EPFL

Transportation research is highly multidisciplinary with contributions from fields such as economics, logistics, sociology, environment, human behavior, material science, civil engineering, IT and robotics. The majority of projects initiated and coordinated by TRACE were carried out by ENAC labs ([TRANSP-OR](#), [LUTS](#), [LASUR](#), [DISAL](#), [VITA](#), [RESSLAB](#), [CNPA](#), [LASIG](#), [TOPO](#), [GEL](#), [HERUS](#)).

Since its foundation in 2010, TRACE has raised more than CHF26 mio for more than 150 projects. About 75% of this funding was provided by car manufacturers like PSA, Toyota, Honda and Renault or multinational giants like Honeywell and Samsung. The remaining 25% are public grants, both European and Swiss. TRACE initiated a dozen [Innosuisse](#) projects, which are funded by the Swiss Commission for Technology and Innovation (see section 6.4.1 for more details on this funding scheme), with a total funding of about CHF3.5 mio. Among these is the project by the laboratory TRANSP-OR (IIC) with [ABB](#) for the electric bus [TOSA](#) and the project of the laboratory LUTS (IIC) with ENAC's spin-off [BestMile](#) for autonomous shuttles.

Since January 2019, TRACE has coordinated EPFL activities in the [EIT Urban Mobility program](#) funded by the European Institute of Innovation and Technology (EIT), whose goal is to improve the urban mobility in Europe by 2030 through innovation, education and business creation. With funding of €1.6 billion, this project will push urban transportation research in Europe for the next seven years. TRACE's contribution will be focused on the pillar of innovation, by giving the opportunity to the EPFL's researchers to initiate new projects with a great diversity of stakeholders in the field of transportation.

6.3 ENAC Programs for Innovation and Tech Transfer

6.3.1 InnoSeed ENAC Program

[InnoSeedENAC](#) is an incentive program dedicated to ENAC researchers that acts at the very beginning of the Tech Transfer and Innovation process, upstream of the programs managed by EPFL's Vice Presidency for Innovation and the [Technology Transfer Office](#). Its aim is to encourage and support ENAC researchers when evaluating the value and potential of their academic work for society.

Motivation – ENAC's pioneering research provides innovative solutions to social, environmental and technical issues. Launching a seed idea for future translation into a product or service for industry or the public sector may be a long and risky journey. An invention can only grow to its full potential if it is nurtured properly, which takes training, time, a network and financial support. For these reasons, InnoSeed's mission is to offer a program that encourages and eases the first step on the path to innovation, technology transfer and entrepreneurship for promising ENAC projects.

Targeted Actions – The InnoSeed program has four aspects (Figure 6.1):

- Stimulate awareness of technology transfer and engage the entrepreneurial spirit within the ENAC community, e.g., by organizing seminars and workshops
- Provide targeted financial support to promising ENAC projects on a competitive basis
- Connect ENAC researchers to private and public entities through the Industrial Liaison Officer (section 6.3.2)
- Mentor ENAC members with regard to the EPFL and Swiss entrepreneurship ecosystem

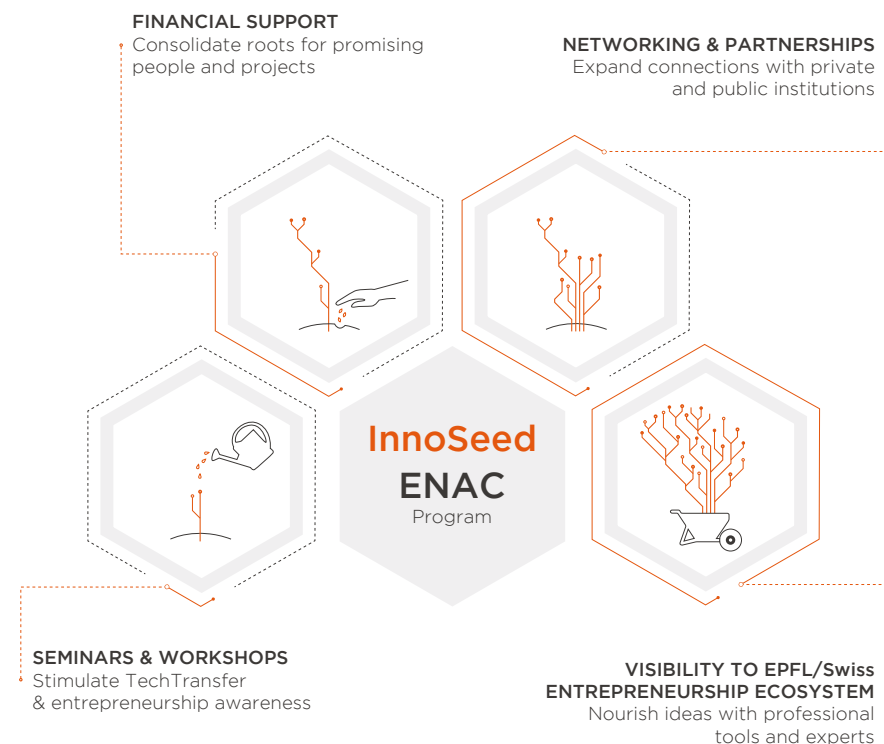


Figure 6.1. Framework of the InnoSeed ENAC program.

Support Offered – The InnoSeed financial support is a unique funding opportunity for ENAC researchers who, based on their research results, wish to develop an application, product or service with a real societal impact. The grants cover outsourcing and equipment in order to refine the proof-of-concept, to create a prototype or to develop the business model (up to CHF60k per project, 6-9 months duration). In addition to the InnoSeed team who provide guidance to the grantees during the project duration, InnoSeed funds business coaching by professional experts when needed.

Successes – InnoSeed ENAC was launched in February 2017 and in less than two years, 15 projects from the three ENAC Institutes were supported by the program. All projects were sustained with individual coaching and strategic support. Subsequently, proposals were accepted by EPFL-based and federal-level innovation-support programs. One [EPFL Inno-grant](#) and one [Venture Kick](#) first stage grant were obtained by project leaders. Moreover, three of the projects supported by InnoSeed led to spin-off companies ([Medusoil](#), [Oculight Dynamics](#), [Enoki](#)), and two patents were registered.

Two of the 15 InnoSeed grants were assigned through an initial joint call by the InnoSeed and [Enable](#) program, which is managed by the EPFL Technology Transfer Office.

This collaboration, amongst others, shows that the InnoSeed program found its niche in the existing innovation ecosystem at EPFL – it is an ENAC-only program that supports the maturation of early-stage projects upstream of existing innovation-support initiatives.

Fostering Entrepreneurial Spirit – In addition to supporting specific projects, InnoSeed ENAC organized eight events gathering more than 300 participants, offering the ENAC community the opportunity to learn how to generate, protect and communicate ideas, and to understand the business potential of open knowledge. The InnoSeed program is well anchored in the ENAC community with more than 1500 website visits in 2017/2018 and more than 300 followers on Twitter.

Outlook – With the program's success, we aim to continue raising the visibility of the program, especially to PhD students and postdoctoral researchers, with the goal of increasing the spirit of technology transfer and entrepreneurship in ENAC. Coaching for projects/candidates will be reinforced by establishing stronger links with the [EPFL Alumni Mentoring Program](#). This Program, which will run for at least the next five years, targets EPFL graduates and will provide support several projects per year.

6.3.2 Industry Liaison Officer

In 2015, ENAC created the position of Industry Liaison Officer (ILO), attached to the Dean's office. The ILO facilitates the connection with private and public partners, acting as a single entry-point for all research-related enquiries from external parties and advising ENAC research on opportunities for collaboration, technology transfer and industry funding (Figure 6.2).

Companies and government offices frequently come to EPFL with questions and interest for possible collaborations. The role of the ILO is to analyze the request, meet with the company in order to understand the needs and expectations, and outline what ENAC may offer, both in terms of content and format. The ILO therefore acts as a filter and directs selected requests to the laboratories that best match the industry partner's needs.

From these partnerships, ENAC laboratories gain access to data, opportunities for case studies and applications of new technologies, new research questions and/or funding as well as opportunities to maximize the impact of their research on society.

The ILO also offers advice on services supporting startup creation, intellectual property protection, and possible academic partners when larger research consortia are created.

The ENAC ILO works closely together with the EPFL Vice Presidency for Innovation (VPI), to enable:

- Better knowledge of ENAC laboratories and specific research fields
- Representation of ENAC in EPFL-wide initiatives
- Links to other EPFL entities dealing with external partners, such as VPI, Technology Transfer Office, Mediacom, EPFL Philanthropy office, EPFL Alumni and the centers such as the Transportation and Energy Centers

Successful collaborations have been established with companies such as Swisscom, Romande Energie, the Canton of Geneva, Swiss Post, and Toyota.

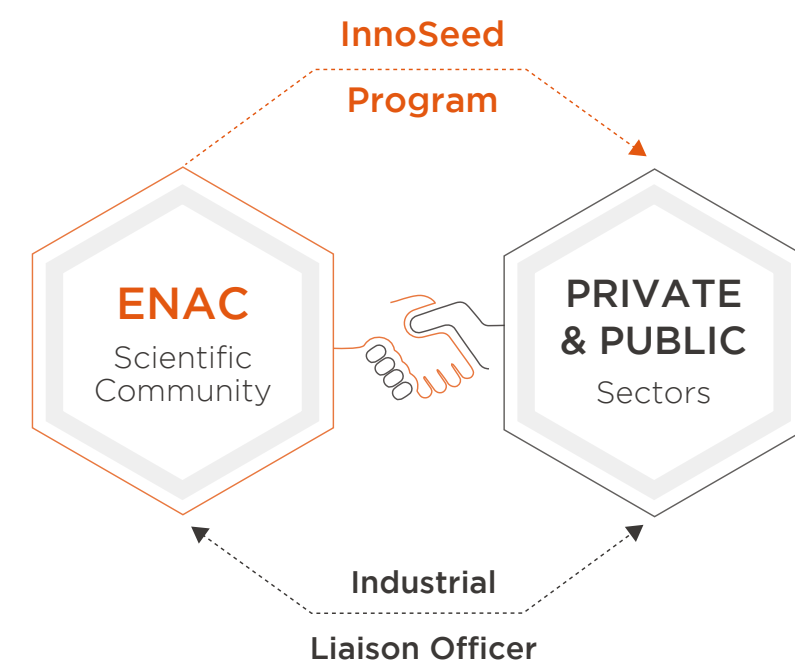


Figure 6.2. Role of the ENAC Industry Liaison Officer.

6.4 Partnerships with Industry

6.4.1 Research Agreements with Industry

ENAC laboratories have been very successful in attracting direct industry funding (Figure 6.3), with external funding increasing again over the last three years since the ENAC Industrial Liaison Officer (section 6.3.2) was appointed. The direct industry funding is now at the same level of the funding from federal offices (Figure 6.3), that remains one of the main funding sources for ENAC laboratories to address societal challenges.

In addition to direct industry funding, the Swiss Commission for Technology and Innovation (previously CTI, now [Innosuisse](#)) – one of the world’s most successful state funding agencies for innovation – offers several funding schemes that promote Swiss innovation potential. The most common funding scheme provides funding to universities for

collaborations with industry partners on projects that have a market potential. Innosuisse provides 1:1 fund matching that covers all salary expenses on the university side, whereas the industry partner supplements 20% of the Innosuisse funding in cash and the remainder as in-kind contributions; the intellectual property rights are assigned to the industry partner, with a free and perpetual back-license to EPFL for applications outside of the partner’s field of use. Figure 6.4 shows that ENAC funding increased significantly between 2013 and 2015, levelling out at approximately CHF1.5 mio/year over the last three years. Almost half of these funds were to establish the Swiss Competence Center for Energy Research (SCCER, section 6.5.3) in Future Energy Efficient Buildings and Districts as well as Supply of Electricity where ENAC played an important role.

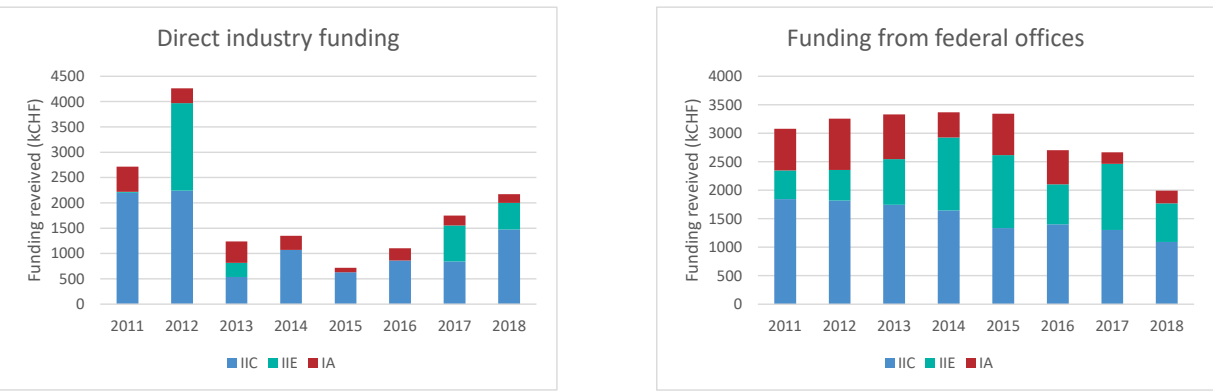


Figure 6.3. Direct industry funding (left) and funding from federal offices (right) received by ENAC laboratories.

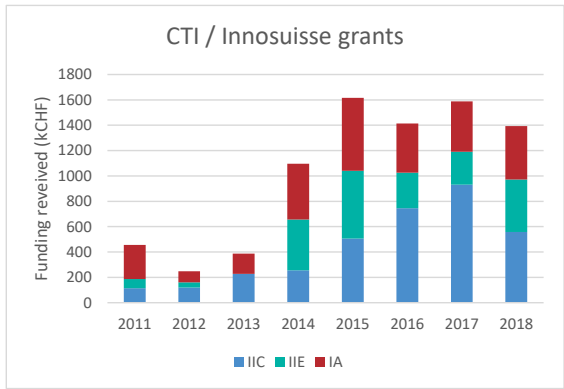


Figure 6.4. Funding received by ENAC laboratories through CTI and Innosuisse grants (based on annual expenditure).

6.4.2 Framework Agreements and Funded Chairs

Over the past decade, framework agreements have been negotiated with several industry partners. Industry partners, with whom such an agreement could be signed, include important players such as La Mobilière and Swisscom, which fund a professorship and a pluri-annual budget for research projects, respectively. These framework agreements serve to facilitate interactions by regulating confidentiality, intellectual property and EPFL overheads, and have been endowed with research funds for funded chairs or competitive calls for proposals. Since 2009, five chairs within ENAC have been funded by industry and private donors, and for a further chair in the area of Extreme Environments (part of ALPOLE, section 5.4.3.6), the recruitment of which is currently underway (Table 6.1).

Table 6.1. ENAC chairs funded by industry and donors.

CHAIR	HOLDER	PERIOD
Landolt Chair: Innovation strategies for a sustainable future	Various + Solar Decathlon sponsorship	2009-2017
Petrosvibri SA Chair in Geoengineering and CO2 Sequestration	Prof. Lyesse Laloui	2012-2019
Gaznat Chair in Geo-Energy	Prof. Brice Lecampion	2015-2025
Margaretha Kamprad Chair of Environmental Science and Limnology	Prof. Alfred Johny Wüest	2012-2022
La Mobilière Chair in Urban Ecology and Sustainable Living	Prof. Claudia Binder	2016-2022
Ingvar Kamprad Chair of Extreme Environments	Recruitment currently underway	10 years

6.5 Technology Transfer to Industry and Public Sector

ENAC researchers use a wide range of approaches to transfer their research results to industry and the public sector. This section reviews the most important ones:

- Start-ups emerging from ENAC laboratories (section 6.5.1)
- The Smart Living Lab as a hub for innovation and technology transfer (section 6.5.2)
- Knowledge and technology transfer through professional practice and project work (section 6.5.4)
- Contribution to civil engineering codes (section 6.5.5)
- Policy advice to governmental bodies (section 6.5.6)
- Contribution to capacity building in the Global South (section 6.5.7)

6.5.1 Start-ups Emerging from ENAC Laboratories

The number of start-ups from ENAC has been increasing in recent years (Figure 6.5). This effect is reinforced by the InnoSeed Program (section 6.3.1) from which three ENAC startups emerged in 2018. It is important to note that, next to start-ups, ENAC graduates also open consulting offices for technology transfer (in particular in architecture and civil engineering). These are service companies and not included in the start-up counts presented in Figure 6.5; accurate numbers are not available. Thus, the number of ENAC start-ups does not reflect the total number of companies emerging from ENAC.

Examples of ENAC start-ups and scale-ups (laboratory and Institute from which it emerged and starting year in brackets):

- [MeduSoil](#) (LMS, IIC, 2018) – MeduSoil applies the world’s first ground bio-stabilization technology to mainstream construction problems. MeduSoil has won several grants (VentureKick, EPFL Innogrants, InnoSeed ENAC) and has been named one of the top 15 startups in Europe as part of the prestigious [SLUSH 2018](#) competition.
- [ENOKI](#) (Solar Decathlon, ENAC, 2018) – Enoki offers consulting on sustainable city development and draws from knowledge developed during the Solar Decathlon competition.
- [Oculight Dynamics](#) (LIPID, IA, 2018) – OCULIGHT offers daylight consulting to promote human well-being in the built environment. It was a finalist in the [Startup Durable SUD](#) competition 2018 by Le Temps.
- [Gamaya](#) (TOPO, IIE, 2015) – Gamaya responds to the need to feed 10 billion people by developing a solution for large scale analytics of farmland based on leading-edge hyperspectral imaging. Gamaya has raised more than US\$7 mio funding for its development.
- [Hydromea](#) (DISAL, IIE, 2015) – Hydromea provides miniaturized underwater swarm robots, leading the way in the affordable Big Data under the water surface.
- [Bestmile](#) (ENAC students, 2014) – The Bestmile mobility services platform is used by mobility providers around the world to deploy, manage and optimize fleets of driverless and conventional vehicles for scheduled and on-demand service. Bestmile established offices in San Francisco and Singapore to serve their global customer base. In 2018, Bestmile was involved in the deployment of the largest fleet worldwide of 150 autonomous vehicles in partnership with Ohmio Automotion in Korea. Bestmile simultaneously collaborates with Swiss city transport operators. It was ranked second in the TOP100 Swiss Startup award 2018, while it raised US\$11 mio funding in the same year.
- [Kaemco](#) (LESO-PB, IIC, 2013) – Kaemco is a specialist consulting office offering a unique service of adding the dimensions of energy and comfort to 3D geometrical data at the urban level.
- [Gaiasens Technologies](#) (EFLUM, IIE, 2010) – Gaiasens offers real-time measurement solutions for extreme environments, modeling services and environmental studies. It has become a major player in Switzerland for the implementation of operational solutions for managing natural hazards.
- [SwissINSO](#) (LESO-PB, IIC, 2009) – SwissINSO developed unique patented nano-deposition technology for the color coating of solar glass Kromatix™, which makes it a pioneer in the development and application of new solar technologies and products targeted at enhancing the aesthetics and overall efficiency of Building-Integrated Photovoltaic and thermal solar energy solutions.

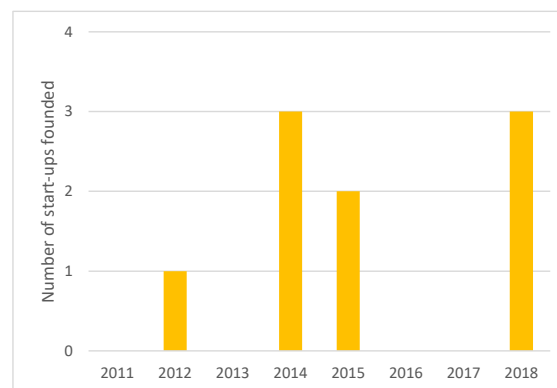


Figure 6.5. Start-ups developed from ENAC since 2011

6.5.2 The Smart Living Lab as Hub for Innovation and Technology Transfer

The Smart Living Lab (section 2.5.1.1) serves as hub for innovation and technology transfer for research on technical, societal, and economic challenges of the built environment. Projects carried out at the Smart Living Lab include technology demonstrators, educational and research projects, social and behavioral studies, and the development of new design methods and processes; examples of projects are listed [here](#). These projects build on collaborations between partners from the private, public and academic sectors. Current partners from private industry are electricity providers, grid operators, lighting system manufacturers, architects, energy and life-cycle analysis consultants, start-ups, and entrepreneurs.

The Smart Living Lab allows partners to tap into unique interdisciplinary competences as well as to use the excellent research infrastructure available at the heart of the Switzerland Innovation Park (SIP) Network West EPFL. More specifically, partners may work with the Smart Living Lab in one of the following ways:

- Contribute to the funding of high-potential research in their sectors of activity through open research programs
- Develop strategic partnerships such as the [student entrepreneurship incubator](#) supported by Baloise (provides funding and coaching for student projects)
- Seek answers to specific questions by carrying out research projects with one or several of the Smart Living Lab research groups
- Use the Smart Living Lab's research infrastructure to develop innovative projects
- Participate in networking and innovation events

Partnerships are developed using the expertise and tools offered by the technology transfer services of the Smart Living Lab partner institutions: EPFL, the School of Engineering and Architecture of Fribourg (HEIA-FR), and the University of Fribourg (UNIFR).

Research Integrated in the Building Design Process of the New Smart Living Lab Building – Since its foundation in 2014, research conducted at the Smart Living Lab has been geared towards defining an innovative design process for the future building (Building2020). The construction of this building will start in 2020 and will be designed to meet the ambitious targets in terms of environmental performance that are part of the Swiss Energy Strategy for 2050. By advancing understanding of individual user preferences, behaviors and interactions, the Smart Living Lab is paving the way to more efficient systems and healthier, more comfortable and more personalized built environments.

The research around the design of this new building has explored novel approaches incorporating questions of environmental impact at early stages. The newly developed tools and procedures are currently used in the process of the design competition for the new building. The professional teams selected for the design competition actively participate in the ongoing research. Leading architectural and engineering firms are therefore part of this living experiment, which aims to introduce novel practices to industry.

A Building as a Full-Scale Experimental Platform – The future building of the Smart Living Lab, which will permanently host 130 research staff by 2022, will offer a platform for testing and demonstrating full-scale prototypes of building components and systems. While currently the research groups of the Smart Living Lab are hosted in temporary facilities, once in the new building, they will have a unique adaptable building to be used as part of their research equipment.

6.5.3 Swiss Competence Centers for Energy Research (SCCER)

SCCER – Supply of Electricity – In the context of the energy transition and reduction of greenhouse gases emissions, comprehensive work is being carried out for the near-future exploitation of deep geothermal energy, implementation of geological CO₂ sequestration, and improvement of energy production from hydraulic power plants. Different IIC laboratories (LMS, GEL, LEMR, LCH) are playing active roles in this program. The interaction with industrial partners aims to promote new technologies and the tools to handle them in order to foster knowledge and technology transfer to engineering practice.

SCCER – Future Energy Efficient Buildings and Districts – The vision of the Swiss Competence Center for Energy Research on Future Energy Efficient Buildings Districts is to develop solutions for Swiss building stock that will lead to a reduction of the environmental footprint of the sector by a factor of three by 2035 thanks to efficient, intelligent and interlinked buildings. This challenge is met combined effort by leading Swiss and international partners from academia, industry and the public sector. The IIC LESO-PB laboratory played an important role in setting-up and implementing this program.

6.5.4 Knowledge and Technology Transfer through Professional Practice and Project Work

In architecture and, to a lesser extent, in civil engineering, knowledge and technology transfer also occurs through professional practice of faculty members. Approximately half the professors of the Institute of Architecture and the City and a quarter of the Civil Engineering Institute own or co-own consulting offices. In addition, ENAC researchers use challenging real case studies for testing their products and validating new methods. IMAC (IIC) and MCS (IIC), for example, have over the last ten years evaluated the performance of various structures and networks using sensors (bridges, water-supply systems, buildings, wind towers, ...) in Europe but also worldwide. RESSLAB (IIC) has performed high-fidelity numerical simulations of various buildings and bridges (including the third Bosphorus crossing), IMAC (IIC) carries out seismic assessments of many cultural heritage structures in Switzerland. All these studies serve to develop the methods further and are carried out in close collaboration with industry partners and owners of the structures.

Prototypes of ENAC technology were also used in the construction of new structures. Some recent examples are:

- IBOIS (IIC) – Research on a new generation of timber shell structures, which combine novel timber connections and automated fabrication processes, have been used in several flagship projects, including the [Vidy Theatre in Lausanne](#) and the [Train Station Complex in Rossiniere](#) (Switzerland).
- CCLAB (IIC) – The capacity of novel composite materials developed by CCLAB has been tested in several applications, such as the [Avançon bridge](#) (Switzerland).
- MCS (IIC) – UHPFRC (Ultra-High Performance Fiber Reinforced Cementitious composite material) technology has been developed and implemented to enhance reinforced concrete structures (bridges and buildings) in Switzerland (about 50 applications) and [first applications](#) in Japan, China, France, Germany and the USA.
- LUTS (IIC) – LUTS developed efficient algorithms to rebalance vehicles in real-time for car-sharing systems (collaboration with Toyota). These algorithms were tested in the field (Grenoble, France) and showed significantly better performance in terms of served demand and vehicle availability compared to state-of-the-practice algorithms. Additional sites in Asia are under development.
- LAST (IA) – The Working Space project aims to develop an innovative, modular and prefabricated timber construction system adapted to the vertical extension of existing office buildings. A first application of this innovative architectural concept was completed in Lausanne and other applications are in discussion with several partners.

6.5.5 Contributions to Civil Engineering Standards

Codes in civil engineering define the current state-of-the-art that is applied in engineering practice. Unlike other domains, they define much more than geometrical and technological requirements. They include relevant physical-principle models, empirical relationships, constraints and the verification methods that are applied when either designing a new structure/system or assessing an existing one. Participating in standardization development is thus not only a service to the society, but it is also a very efficient manner to transfer knowledge from scientific research to engineering practice.

At present, the European Committee for Standardization (CEN) is developing a second generation of Design Eurocodes, which will replace the first set of codes that were developed between 2000 and 2005. Since these codes will be used by about 500,000 structural engineers (in Europe, and also worldwide), this work will have a tremendous impact on civil engineering practice. Development of this new generation of codes involves reinforcing physical principles within analytical models and refining assessment procedures for existing structures, which require more advanced models and analysis methods than new structures. The codes are

drafted by small committees (6-8 per working group), assembled by CEN. Several IIC members serve on these working groups: Prof. Aurelio Muttoni led between 2015 and 2018 the project team in charge of the main part of the European code for concrete structures (EC2-Part 1), Profs. Katrin Beyer and Dimitrios Lignos are in charge of the seismic design chapters for masonry and composite structures (EC8-Part 1), respectively, and Prof. Alain Nussbaumer is part of the project team revising the part of the fatigue assessment of steel structures.

At the national level, Prof. Eugen Brühwiler led the introduction of the new norm SIA 269, which is one of the first civil engineering codes worldwide entirely dedicated to the assessment of existing structures. Several further colleagues chair national code committees (e.g., Dr. Pierino Lestuzzi: SIA 261 Actions on Structures).

At the international level, Prof. Dimitrios Lignos is a member of US project teams developing the next generation of modeling guidelines for assessing the seismic safety of existing structures (ASCE 41-22).

6.5.6 Policy Advice to Governmental Bodies

ENAC is engaged and has a long tradition of consulting and providing expert reports to national and international governmental agencies, which need independent expert judgement of important challenges in society. Members of all three Institutes provide such policy advice with regard to technology transfer. The largest role is played by the Institute for Environmental Engineering (IIE). Governmental agencies seek advice from faculty members of IIE with regard to a large range of topics such as climate change, pollution, wastewater treatment and renewable energy. In particular the joint professorships of the IIE with research Institutes of the ETH domain (Eawag, WSL and PSI) contribute significantly to policy advice. Examples for national expert services include consulting

for renewable energy installations (CYROS laboratory), heat extraction from surface waters or the treatment of cooling water in power plants (APHYS) and phosphorus flows and lifecycle in the national economy (HERUS). International consulting includes methane extraction from lakes in Africa (APHYS), wastewater treatment with respect to bacterial and other pollution and disinfection measures (LTQE) and other remediation work (EML, LBE) as well as work for air pollution monitoring (APRL). Increasingly expertise is asked in the context of climate change and consulting projects include the future of snow, water resources and vegetation (CRYOS, WSL-AR) and the design of future (e.g., biofuel) energy systems (EPFL-PSI).

6.5.7 Contributions to Capacity Building in the Global South

ENAC is particularly well placed to contribute to the [SDGs](#) through its expertise in large societal problems as well as its expertise in interdisciplinary research. Indeed, a recent survey at EPFL showed that ENAC labs contribute to all the SDGs. ENAC contributes to capacity building in the Global South through collaborative research projects, MOOCs (section 4.5.2) and collaboration with national and international development agencies.

At EPFL, the [Cooperation and Development Center at EPFL](#) (CODEV) promotes innovative technologies to support social, environmental and economic development in the Global South. It supports collaborations between EPFL laboratories and stakeholders in the Global South through Seed grants. These impact-oriented research projects are valuable instruments to enable research partners in the Global South to access innovative technologies and methodologies through

knowledge transfer from EPFL. Between 2011 and 2018, ENAC researchers were granted 26 research projects through the EPFL Seed Funding Program managed by CODEV. One example is the project led by Prof. Rizlan Bernier-Latmani (EML, IIE) analyzing arsenic pollution in groundwater in Vietnam. The project exposing Vietnamese students to high-level scientific investigation building their methodological skills. As a result of this project, a solid scientific basis is now available that identifies the origin of the arsenic and lays the foundation for developing an economically viable approach for removal of this toxicant from water. In another project, the Laboratory of Geographic Information Systems (LASIG) collaborated with the Kuzikus Wildlife Reserve and Drone Adventure, two NGOs, to produce accurate maps of animal and fodder distribution in the Namibian semi-arid savanna to favor sustainable land use management and biodiversity conservation using ultrahigh-resolution imaging from drones.

6.6 Patents, Licenses and Open Science Research Products that are used in Industry

As described in section 6.2, the principal missions of the EPFL Technology Transfer Office is to help shape the innovative content of technologies developed in the EPFL laboratories and to provide help and support in the writing and filing of patents. The Technology Transfer Office has, over the past few years, developed a comprehensive set of tools to support laboratories to transfer knowledge to industry. This includes well-defined yet flexible intellectual property models at different EPFL overhead rates for interactions with industry, as well as detailed support of patenting activities. Moreover, the Technology Transfer Office has adapted their traditional service approach to encourage laboratories to secure their intellectual property at the start of a project with an industry partner. After an assessment of the novelty and

innovative nature of an invention disclosure, the Technology Transfer Office helps identify suitable patent attorneys to assist in patent writing and filing, and typically covers the attorney fees as well as the costs of the initial filing. Particularly in the case of Tenure-Track Assistant Professors, the patent maintenance fees are typically covered until the patent application enters the national/regional phases.

This proactive and systematic approach has resulted in a continuous increase in ENAC patent applications in recent years (Figure 6.6a), followed by licenses and technology transfer agreements (Figure 6.6b). Similarly, there is a steady flow of invention disclosures and new software (Figure 6.6c).

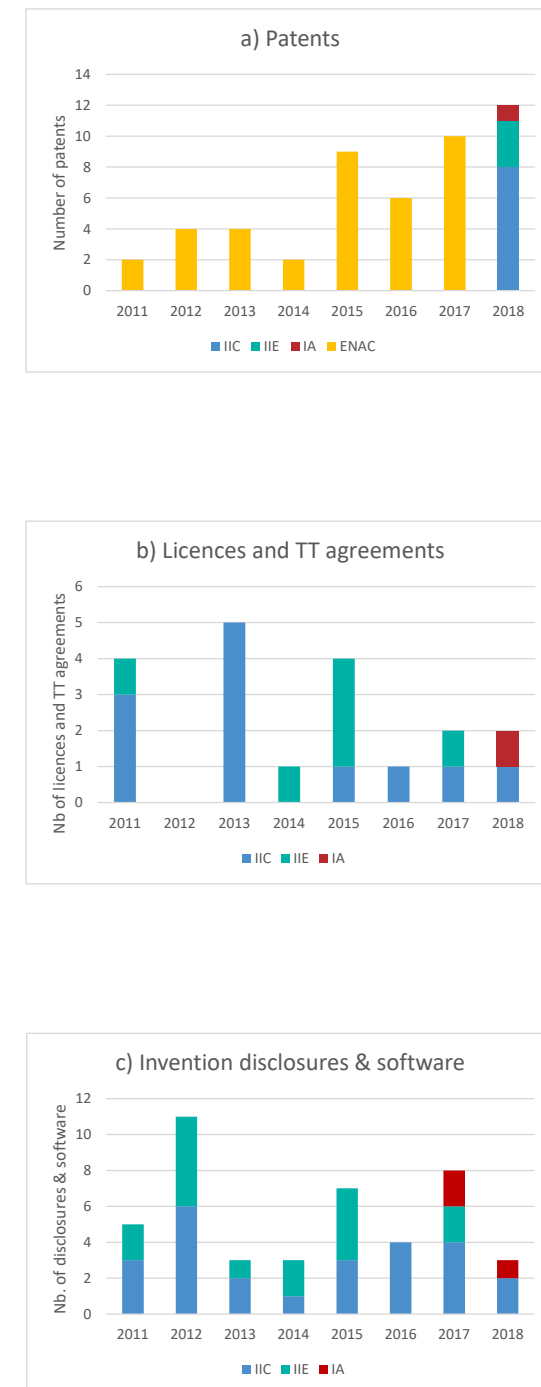


Figure 6.6. Number of patents (a), licenses and tech transfer agreements (b) and number of invention disclosures and new software (c) from ENAC since 2011.

In keep with the goal of open science, many ENAC laboratories share their research results openly. Several of these results, in particular software, are used by researchers at other institutions and by industry. The following is a list of examples of such open research results:

- [Meteolakes](#) (APHYS, IIE) – Meteolakes is an online platform for monitoring and forecasting the bio-physical state of Swiss lakes. It is used daily by a wide community of users with different profiles, including fishermen, municipal drinking water utility companies, emergency services, beach managers and leisure users.
- [Biogeme](#) (TRANSP-OR, IIC) – Biogeme is an open source Python package designed for the maximum likelihood estimation of parametric models in general, with a special emphasis on discrete choice models. It is used as a research tools by many PhD students around the world. It is also used as a teaching tool by several universities in transportation curricula, but also in economics and marketing. Finally, it is used by professionals in transportation (including Swiss Rail) and marketing.
- [Akantu](#) (LSMS, IIC) – Akantu is an open source object-oriented finite element library built to be generic and efficient. It is used by several research groups worldwide, and has led to collaborations with the watch industry for contact predictions and the construction industry for seismic simulations of dams.
- [Jconc](#) (IBETON, IIC) – Jconc is an open-source finite element program to calculate elastic-plastic stress fields for structural concrete members. It is used by a number of specialized design offices in Switzerland and Norway.
- [Numerical Models for Snow, Meteorology and Hydrology](#) (CRYOS, IIE) – A github site features a range of snow and meteorological models, which are used worldwide for operational services such as avalanche warning or hydrology. The models are a product of WSL to which CRYOS makes a substantial contribution on a regular basis.
- [MoTUS](#) (LESO-PB, IIC) – MoTUS is an online platform for monitoring and modeling of high-resolution meteorological vertical variables in urban sites and districts. It is used to determine the impact of urban microclimates on the energy demand of buildings, air pollutant dispersion and renewable energy potential in urban planning scenarios.
- [Geronimo](#) (LESO-PB, IIC) – Geronimo is a user-friendly software package for architects and lighting designers conceived to perform daylighting calculations. It allows visualizing the impact of Complex Fenestration Systems (CFS) in office buildings for different sky types (overcast and clear skies).
- [CitySim Solver](#) (LESO-PB, IIC) – The CitySim Solver is a decision support system for urban energy planners and stakeholders to minimize the net use of non-renewable energy sources as well as the associated emissions of greenhouse gases.
- [IIDAP](#) (RESSLab, IIC) – IIDAP is a finite element package with interactive interfaces that enables large-scale parametric nonlinear dynamic analyses with an emphasis on quantifying the earthquake-induced collapse risk of structures. It is used as a tool by a broad range of structural engineering firms around the world, the (re-)insurance industry as well as in graduate courses in top academic institutions in the US and Canada. It has also been used in major research-to-practice projects (e.g., ATC-76-6) funded by the US National Institute of Standards and Technology.

6.7 Collaboration and Exchange with Industry as Part of Education

Internships in Industry – In all three Bachelor/Master programs, internships in industry are an important and mandatory component. The minimum duration of the internship varies between the three sections (SAR: 12 months, other sections: 2 months). The reports submitted by the students and the evaluations by the hosting firms show how important this period of professional practice is in learning how to organize work, and how to approach real issues. Also, it is observed that the internship represents an excellent opportunity for the students to better define the content of their Master degree studies and to demonstrate their competences, given the potential to find a first job in the internship's enterprise. More information on internships as part of the curricula can be found in sections 4.2.2.2, 4.2.3.2, and 4.2.4.2.

Semester and Master Projects in Collaboration with Industry – In addition to internships, students can also perform semester and Master projects in collaboration with industry. In Civil Engineering, this has been practiced with ad hoc agreements in the past. From 2019, the option of carrying out the Master project in a company will be formally introduced on the basis of EPFL rules for such Master projects, which regulate supervision but also IP aspects. In Architecture and Civil Engineering, members of the profession are invited to participate in project juries offering a further opportunity for exchange between the Faculty and professional practice. In Environmental Sciences and Engineering, the Design Project is an opportunity for the students to take part in a project proposed by industrial partners, companies and governmental bodies. This project is mandatory and involves around 25 external partners every year, in collaboration with academics in the Section.

Exchange with Industry and Professional Associations – Advisory boards with members from industry and professional associations are regularly consulted by the Civil Engineering and Environmental Engineering Sections, with a focus on curriculum development (sections 4.2.3.3 and 4.2.4.3). All faculty members belong to various national and international professional associations, often in leading positions (see Volume B). Further ties with professional associations exist on the ENAC level in a formal exchange with [60 professional associations through Switzerland from all fields related to the three Institutes](#). Regular meetings between the professional associations and the ENAC Dean serve to maintain two-way connections between the Faculty and the professions. For instance, new professors introduce themselves, and student internships are proposed. The supply of graduates in different areas is relevant for the professional associations, e.g., open positions in engineering, urbanism and architecture can exceed the supply despite the significant numbers of students from ENAC entering the professional world each year.

In Civil Engineering, the performance of ENAC students in their studies or in a specific field of study is supported by various companies, foundations or associations through prizes awarded on the basis of performance indices or on the basis of particularly outstanding study projects. Also, the Civil Engineering Student Association (AEGC) launched in 2018 the first edition of its Forum GC, where Civil engineering companies have the opportunity to present themselves to ENAC students and to discuss future professional opportunities.

6.8 Knowledge Transfer to the Society at Large

Socio-economic and political awareness about climate change, sustainability, transportation and urban planning is growing, thus placing ENAC at the center of public debate. ENAC is strongly committed to communicating with the public about its research, expertise, innovation, technical transfer and education programs. To do so, ENAC employs a communications officer and a journalist trained in science communication and up-to-date communication tools.

In 2012, the Transportation Center appointed another journalist who covers ENAC research in this domain.

This section gives an overview on ENAC's participation in outreach events, coverage of ENAC in the news and involvement in social media, ENAC's annual report, exhibitions organized by ENAC as well as citizen science projects of ENAC researchers.

6.8.1 Outreach Events

ENAC's active contribution to annual EPFL outreach events such as the *Drone Days* (targeting a large public), *Scientas-tic*, the *Journée des gymnasiens* (high-schools) and *Journée osez tous les métiers* (targeting the young public) and *Energissima* (targeting industry) allows the presentation of its activities and educational programs to different target groups. In 2017, the EPFL Open Days saw thousands of people visiting the campus. ENAC laboratories organized original and

fun tours and demonstrations. The same year, two of the three EPFL labs (VITA and LESO-PB, both IIC) participating in the Swiss Digital Day were from ENAC. This annual event targets a broad audience and aims to show the influence of digitalization on daily life. For its first edition, the [Swiss Digital Day](#) united 70 partner organizations and took place in twelve Swiss cities.

6.8.2 ENAC in the News

The ENAC journalist and the Transportation Center journalist publish about four press releases a month as well as internal news informing the ENAC community about awards, new appointments and special events. All these news appear on ENAC [front page](#). The press releases showcase ENAC's achievements with regard to its three core missions – research, education and innovation. Each press release is typically followed by several articles in the media.

The importance of communicating science using videos has globally increased, as it has in ENAC. Because the production of videos is very time-consuming and video communication is not chosen as a strategic medium by EPFL, video production in ENAC is not systematic at present. Many examples of ENAC news videos are, however, available on the [EPFL YouTube channel](#) (over 18k followers).

Of particular note is the 2017 victory of the ENAC team in the US Solar Decathlon, which attracted unprecedented attention from the national and international media. This ambitious interdisciplinary [project](#) (section 4.4.2), led by Prof. Marilynne Andersen, showcased the creative depth of ENAC to a large audience.

ENAC researchers regularly engage in knowledge transfer to the public by interactions with the national and international media. In Switzerland, their expertise is a valuable source of objective and scientific information. Indeed, this serves as an important contribution to the Swiss system of semi-direct democracy. As a result, ENAC experts appear almost every day in the daily [EPFL Press Review](#) by [Mediacom](#) (EPFL's press office). The ENAC communication officer supports the researchers in preparing such statements.

Examples of ENAC coverage in international media:

- New York Post, 7 January 2017, [City living is making you fat](#)
- Der Standard, 19 May 2017, [Biologen entdecken Klimawandel-resistente Korallenart im Roten Meer](#) (Biologists discover climate change-resistant coral species in the Red Sea)
- Haaretz, 26 June 2017, [Last reef in the world likely to be in Israeli waters](#)
- Le Monde, 23 August 2017, [On essaie de vendre aux Africains un concept de ville élaboré dans les conférences internationales](#) (We are trying to sell Africans a concept of a city developed in international conferences)
- Denver Post, 16 October 2017, [University of Denver team comes third as Swiss team takes first in Solar Decathlon 2017](#)
- Newsweek, 2 November 2017, [Our ancient ocean temperature records may be wrong...](#)
- Le Monde, 7 March 2018, [La stratégie qui touche le choléra au cœur](#) (The strategy that addresses cholera at the heart)
- Le Soir, 18 June 2018, [House 3, comme un arbre dans la ville](#) (House 3, like a tree in the city)
- Wired, 16 August 2018, [A mind-bending avalanche animation that could save your life](#)
- Reuters, 18 September 2018, [Scientists investigate icy streams for survival clues](#)
- India today, 21 September 2018, [4-year quest to find what, apart from water, is lost when glaciers melt](#)
- Pacific Standard, 8 January 2019, [Why solar panels should go from rooftops to mountaintops](#)

6.8.3 ENAC and Social Media

Since the last Audit, ENAC increased its visibility on social media by monitoring them on a daily basis and giving them a strategic purpose. On 30 January 2019, its [Facebook account](#) registered 2208 followers (up from 1000 on 21 December 2016) (47% women), with 75% aged between 18 and 34 years. ENAC students, researchers, professors and alumni compose the majority of this community. The Facebook page is a catalyst of ENAC's diversity and uniqueness, and keeps members informed about projects conducted by its students and laboratories. It regularly features interviews with ENAC researchers to share their expertise with a broad community.

[ENAC's Twitter](#) account registered 804 followers on 30 Ja-

nuary 2019 (193 on 8 December 2016) (29% women). With its Twitter account, ENAC aims to inform academic and industrial partners, and media outlets who specialize in ENAC topics about its activities. The account also reposts important news from EPFL or Swiss institutions to its community.

Finally, ENAC researchers (especially from IIE) regularly contribute to the [EPFL Out There](#) blog, which is dedicated to scientific missions abroad. With an entry on EPFL's main webpage and regular posts on a [dedicated Instagram account](#) (about 1300 followers) and on EPFL social media (Facebook: 76,700 followers; Twitter in French: 37,700 followers; Twitter in English: 32,800 followers), the blog supports the international outreach of ENAC researchers.

6.8.4 ENAC and EPFL Annual Reports

To inform politicians, academic and industrial partners as well as in the spirit of accountability, ENAC publishes an [online Annual Report](#). This document is prepared in coordination with the [EPFL Annual Report](#), which also includes ENAC's main achievements in a shorter version. In 2014, ENAC

was the first faculty at EPFL to stop printing its report. This ecological initiative was followed by other EPFL Schools and, in 2019, by EPFL itself. The report is widely advertised through direct alerts.

6.8.5 Exhibitions

The [ARCHIZOOM](#) platform, based at EPFL, promotes research and education programs in architecture through exhibitions and conferences opened to the public. ARCHIZOOM also takes part in the *Nuit des musées* annually organized by the city of Lausanne, which gives visibility to ENAC activities. ARCHIZOOM and the Section of Architecture (SAR) also work with [the Forum d'architectures](#) (f'ar) based in Lausanne to display Master projects; each exhibition is followed by the

publication of a book with the best examples. In coordination with ARCHIZOOM, the [Modern Architecture Archive](#) (ACM) actively promotes its research through successful exhibitions accessible to the public and taking place outside of EPFL. These initiatives also allow researchers of the Institute of Architecture to network with Swiss and international stakeholders in cultural policy.

6.8.6 Citizen Science

ENAC regularly uses citizen science to conduct its research, particularly in geomedicine, transportation and urban studies. These initiatives demonstrate ENAC's efforts to improve people's daily life and well-being in an inclusive way. Some recent examples are:

- 7 February 2018, [Confirming the risks of pesticide use in Burkina Faso](#)
- 27 February 2018, [Halting the spread of cholera through a neighborhood response](#)
- 23 April 2018, [Frequent walking: From personal health to sustainable mobility](#)
- 2 May 2018, [Why public spaces in European cities are becoming homogenized](#)
- 5 June 2018, [Night-time noise has damaging effects on Lausanne residents](#)
- 25 October 2018, [Improving breast cancer screening through geomedicine](#)
- 29 November 2018, [Connected urban planners can better serve city residents](#)
- 24 January 2019, [I've decided to give up my car](#)

6.9 Conclusions and Outlook

Since the 2011 Audit, support for technology transfer, innovation and communication in ENAC has been professionalized and intensified. This was achieved through establishing the InnoSeed ENAC program and the creation of new positions (InnoSeed program manager, industry liaison officer, communications officer, journalist). This new structure has already brought first successes (e.g., increase of agreements signed with industrial partners, increase in number of startups emerging from ENAC); it is expected that these positive effects will continue to grow in the years to come.

The approaches taken by ENAC researchers to ensure implementation of their research results are as diverse as ENAC's research itself. Founding startups and filing patents are common steps in technology transfer. Policy advice, contributions to civil engineering codes and transfer through project work are also important when disseminating research results to practice and policy makers and ENAC researchers are active in these areas. There is potential for further technology transfer within the ENAC community, however. The following paragraphs outline future opportunities as well as challenges.

Platforms as Hubs for Innovation and Technology Transfer – The Transportation Center (TRACE) has been very successful in linking industry and research relating to all aspects of transport and mobility. It stands out as a hub for innovation and technology transfer with dedicated staff having domain-specific knowledge acting as liaison officers. This concept has been extended to other areas of ENAC research through the Smart Living Lab and is also applied in the Swiss Competence Center for Energy Research (SCCER), in which ENAC researchers actively participate. The Smart Living Lab is developing its potential as another integrated, multi-institutional hub. It is expected that the importance of this novel platform for transfer of innovative building technologies will continue to develop. Another center embedded in ENAC is the [Habitat Research Center](#), which contributes to the transfer of research results to society in the domain of urban planning. The Limnology Center is leading several institutions in its dedicated [platform](#) for physical and ecological research, installed near Pully in Lake Geneva (more information on centers: section 2.5).

Entrepreneurial Spirit – The InnoSeed Program provides new funding opportunities and support services for technology transfer. Also, this program fosters the entrepreneurial spirit of the ENAC community through the organization of

events on topics related to technology transfer and innovation. Future developments will extend this culture to ENAC students. The Student Kreativity and Innovation Laboratory (SKIL, section 4.4.3) and the [student entrepreneurship incubator supported](#) by Baloise at the Smart Living Lab (section 2.5.1.1) are first, important steps in this direction. EPFL also encourages student entrepreneurship by means of the [XGrants](#) and [YGrants](#) supporting EPFL students who want to launch their own company or social enterprise. Furthermore, Master students have the opportunity to do a Minor in Management, Technology and Entrepreneurship, a very popular option in ENAC and elsewhere in EPFL.

These existing offers will soon be complemented by a course on Innovation for Construction and the Environment, which will be taught for the first time in the autumn of 2019. The course focuses on how innovation impacts traditional civil engineering practice and the environment. It will provide hands-on examples that showcase how new ideas generate change and can help to address large societal and environmental challenges related to resource depletion, climate change mitigation and adaptation. The course will contain creativity sessions, surveys, and in some cases, development of models or prototypes. The aim is to present tangible proposals on improvement of processes, systems and/or materials. Students developing promising proposals will be given the opportunity to study these more in depth in their Master project.

As more laboratories follow open science principles when publishing their research results, a future challenge will be to present, discuss and illustrate case studies of business models around open knowledge. While InnoSeed has already organized a first workshop on this topic, further input is needed. Exchange across campus with all open science actors will be sought by means of [EPFL's Open Science Initiative](#).

Currently Untapped Opportunities – ENAC's research addresses many challenges related to the SDGs and often collaborates with partners of the Global South to build capacities and support the development of tailored solutions. A stronger collaboration with the international organizations in Geneva is desirable. To establish these links, ENAC shall collaborate closely with the new EPFL office, [Tech4Impact](#).

ANNEX

Audit Recommendation and Responses (2011 and 2014)	132
Report of the Audit Committee, December 23, 2011	146
Survey on the Professional Integration of EPFL Master Graduates 2013-2016	157
Bachelor Program Flyers	
Architecture	164
Civil Engineering	168
Environmental Sciences and Engineering	172
Master Program Flyers	
Architecture	176
Civil Engineering	180
Environmental Sciences and Engineering	184
Doctoral School Program Flyers	
Architecture and Sciences of the City	188
Civil and Environmental Engineering	192
Mechanics	196

Audit Recommendation and Responses (2011 and 2014)

1. Concept of ENAC

Audit findings and recommendations

Inevitably, ENAC is a complex heterogeneous organization whose long-term goals must bring together diverse scientists, engineers, architects and social scientists. This is a unique experiment among leading academic institutions (worldwide). The Audit Committee believes it is important to endorse the concept of ENAC while recognizing that the School has much to do in order to fulfill its potential and the high aspirations of EPFL.

Response in 2011

Outstanding hires of new Faculty and staff. We envision outstanding new hires that need to be made in the short term, especially in Architecture, Civil Engineering and Urban Systems Engineering. These persons should necessarily be attracted to ENAC for the opportunities to open new generation collaborative research lines with colleagues in ENAC and throughout EPFL.

Continue the recruitment of competitive students at the BS/MS/PhD levels and provide the educational environment for their long-term career success, since students often change career paths even upon the completion of their degree. ENAC is pleased that the number of women continues to grow in all sections. The faculty will continue to work to make itself a welcoming environment for all students.

Continue to establish a comprehensive system to support faculty and staff development. In particular, the Assistant Professors (PATTs) should be appropriately advised in their advancement (including: annual review by tenured faculty, mid-term assessment with an expert in the field who visits the laboratory).

Develop further the graduate school in ENAC, including coordination of graduate student seminar series, an annual ENAC research day, formal teaching programs and advanced classes that reach across the sections.

Follow-up in 2014

IA: 7 new faculty members have been hired in 2013. There is one urgent need for a Professor in Construction for Architects, the position is planned for 2015, together with a position in Theory of Architecture.

IIC: reinforcing IIC is the priority in ENAC. The IIC strategy envisions 4 main domains to be strongly strengthened to reach an attractive critical mass.

IIE: The strategy follows that earlier presented, with rethinking in the areas of Environmental Fluid Mechanics.

Ongoing

For PATTs: ENAC has in place compulsory midterm reviews, and annual reviews by tenured faculty members.

The annual ENAC Research day is focused on PhD works with prizes. An exhibition of PhD's posters exposes doctoral research to the public.

SeminApero events are organized by ENAC PhD students, and a seminar series in IIE.

Continue to strengthen undergraduate cross-disciplinary teaching, including: 2nd year Semaine ENAC, 3rd year UE (Unités d'enseignement) ENAC, year 4-5 ENAC projects, applied mathematics, systems engineering, ENAC retreats and "Green Days" (focused, off-campus discussions).

Continue to build formal ties with the research Institutes of the ETH domain. We have expanded substantially the formal connections with Eawag with the joint appointments of Profs. Samuel Arey, Urs von Gunten, Janet Hering, Kristin Schirmer and the anticipated joint appointment of one more colleague in aquatic physics shortly. With WSL, we are delighted by the ongoing collaboration thanks to Prof. Alexandre Buttler and the recent joint appointment of Prof. Michael Lehning (WSL SLF-Davos). We also look forward to the anticipated joint appointment with the incoming director of the WSL. With PSI we are pleased with the joint appointment of Prof. Christian Ludwig and look forward to further connections in energy research and are active in discussing possibilities for joint appointments with Empa in Civil Engineering.

Strive for excellence in scientific research with renewed energy and drive. Balance increasing student numbers with resources. Maintain the research office in ENAC for updates on funding opportunities particular to ENAC and support more proposal preparation.

Continued engagement and coordination with the Professional Associations with formal meetings each semester, teaching advisory boards including professional engineers and architects, design projects and internships developed with industry.

Continue to strengthen the development of the Landolt Chair for a Sustainable Future. This involves hosting outside visitors for the Chair each year who teach courses of broad interest for EPFL students and who advise MS and PhD students. In the context of the chair we hold some 3 to 4 major international distinguished seminar speakers that attracts substantial interest from within EPFL and in the region.

Reinforcement of Semaine ENAC and UE ENAC, by revising the offers, and renewal under stronger criteria of multidisciplinary.

New joint appointment with Eawag: Prof. J. Wüest, in 2012.

Prospective collaboration with Empa in the Fribourg Smart Living Lab, and with GL Bona on an energy joint appointment. To be discussed further in 2014.

To collaborate with Research Office EPFL as a strong support in ENAC, Dr. A. Guillemin has been hired as scientific deputy to the Dean, to identify technology transfer opportunities and support ENAC research laboratories to establish new partnerships with industries.

Ongoing

A new agreement has been defined for Landolt Chair and better use of the funding – it will finance the Solar Decathlon project, with its emphasis on sustainability, as a competition on solar energy-based habitation.

2. ENAC Strategy

Audit findings and recommendations

The leadership of ENAC did not convey to the Audit Committee a clear strategic plan for the next five-year period. Although the Self-Assessment Report (Vol. A) includes strategic objectives from each of the four Institutes, the Committee believes these should have been condensed to produce an ENAC plan with future trends, goals and prioritized actions. What is needed now is a realistic plan with clear actions for achieving the goals.

Response in 2011

The ENAC strategy of development for the coming years is clear and as noted by the audit committee consists of: 1) establishing a leadership profile for energy-related research, 2) developing expertise in urban systems engineering, 3) strengthening the PhD program in Architecture and Sciences of the City, in particular by centering its mission on the development of new forms of architectural research.

Leadership in energy-related research: The challenges Switzerland and Europe face are enormous and the real opportunities for research and education development span the spectrum from wind energy, hydro systems, underground storage of CO₂, transportation, urban engineering to the renovation of buildings and new sustainable architectural designs. To date ENAC has strategically hired to reinforce and develop new strengths in this area including the appointment of professors in sustainable architecture and renovation, transportation and air quality engineering, wind energy and water resources systems including hydrology, environmental fluids, and water/waste water treatment. We have also had the pleasure of being awarded an endowed chair in CO₂ sequestration that has allowed us to position ourselves more strongly in this growing domain of research. Our strategy is to continue along these lines, including immediate hiring plans in geotechnical engineering related to questions of underground energy development, light-weight structural engineering, sustainable architectural design

Follow-up in 2014

With a new Dean and new ENAC direction, the strategy has been discussed extensively in a Green Day in August 2013. The main decision in terms of hiring was to support IIC to build critical mass according to its strategy, as mentioned above. Another important decision was to strengthen ENAC in aligning its research and training into the 3 main pillars of the School: Architecture, Civil Engineering, and Environmental Engineering. The 4th Institute, INTER, which is transversal but too small, was dissolved and its participants joined the other Institutes, according to their academic profiles. The project USE (Urban Systems Engineering) will be used as the basis for Digital Urbanism, as identified as a possible Master in the frame of Digital Humanities.

Collaboration with new Director (B. Smit) of the Energy Center has been discussed, in readiness for his arrival in Summer 2014. A position in Geo-energy is ongoing, plus the Valais (Sion campus) position Ecohydraulics.

and construction, and urban systems engineering for the planning of future cities. In brief, ENAC has the vision to take the international lead in energy research concerning the co-evolution of the built and the natural environments, with a keen eye on European culture, and based on all the opportunities that cutting-edge science and technology provide today.

Developing expertise in urban systems engineering: ENAC is fortunate to have the Institute of Urban and Regional Sciences and broadly defined active research interests across the School among faculty and students. A minor in this field is already in place. Decisive steps have already been taken to develop a BS/MS program in Urban Systems Engineering that is placed centrally in ENAC so that students can take full advantage of the richness of all that is offered from the start of their studies. Similar to the Center for Transportation, we are developing plans for a Center in Urban Systems, and in the most recent calls for NCCR proposals from the Swiss Science Foundation two proposals for research in urban infrastructure and the development of the built environment in the Alps were proposed. Future faculty hiring will be critical to strongly develop this field.

Strengthening the PhD program in Architecture and Sciences of the City (EDAR): Though historically there has been less of a tradition in architecture to continue on academically and to earn a PhD (outside of history, theory and urban sciences), this doctoral program is steadily growing at EPFL. We are opening two new tracks of study in sustainable architecture and a doctorate in design. Core classes are being designed (some are already implemented) to further develop the sense of an open intellectual community of graduate student scholars in architecture, as opposed to just individually defined plans of study and research toward a PhD degree.

Success in these three areas will be measured by the continued quality of the recruitment of new faculty in these domains, the implementation of intellectually challenging new plans of study in Urban Systems Engineering and the start of the new center, and the growing quality of PhD theses in Architecture and Sciences of the City.

In a recent ENAC Faculty Green Day on the theme of urbanism, working groups proposed interesting ways to develop a new discipline.

The necessity of a strong anchorage contributes to the decision to focus on IA, IIC and IIE as Institutes aligned with teaching disciplines, and to strengthen them with the redistribution of resources from INTER.

A center on the theme of territory and urbanism will be created around transversal projects, launched by means of incentives.

3. Management Structure

Audit findings and recommendations

The Committee believes that more cooperation and collaboration amongst the Institutes is essential for the long-term health of ENAC.

Response in 2011

The ENAC Direction, which consists of the Dean, the four Institute directors and three additional faculty members, operates via regular bi-weekly meetings. Each month we also meet formally with all the directors of the undergraduate and graduate programs, and the various standing and critical ad hoc committees. The entire faculty (professors & MER) meets one or two times each semester. A broad school assembly meeting is hosted each fall where students, staff and faculty present and update along with a full day off-campus faculty retreat at the end of the summer to plan ENAC strategic initiatives. We hold meetings of the School Council twice each semester to support broad consensus building and information transfer across all ENAC personnel. Contrary to the initial impression of the Audit Committee (possibly due to the structured format of the intense meeting visits that took place over four days), there are indeed remarkable connections and collaboration across the Institutes in ENAC and great efforts have been taken through the years to broaden both formal and informal interactions.

Follow-up in 2014

The ENAC Direction has been revisited and is now composed of Dean, Institute and Section Directors. This enables a full communication on all the strategic topics, full understanding and common decisions in new hiring, and better coordination between research and teaching, being major missions of our Institution.

The internal reorganization, started in 2008, to strengthen the main institutes and aligning disciplines, is continuing with the decision to suppress INTER as a separate institute, and to envision the creation of a strong center dedicated to urbanism, as this theme is transversal in ENAC.

The simplification of the structure and alignment of disciplines enables a better visibility with a stronger critical mass in each domain, making ENAC more attractive to potential candidates.

4. Urban Systems Engineering

Audit findings and recommendations

The Audit Committee supports Urban Sciences as an integrating theme, but believes that new research and education programs should be developed through planning and participation of all institutes within ENAC. The Committee was encouraged by the initiation of multidisciplinary research Centers, such as the Transportation and Mobility Center (TraCE), as a model for engaging faculty across Institutes within ENAC and between Schools.

Response in 2011

We appreciate and agree fully with the advice to focus efforts on Urban Systems Engineering (as opposed to pure urban planning which will take longer to build capacity) and to take full advantage of all that ENAC has to offer in Engineering and Architecture. Our development of teaching (BS/MS) in Urban Systems Engineering will of course be complementary to programs at the Universities of Lausanne and Geneva, and we also have formal discussions underway with ENS Lyon and Ecole des Ponts to build formal connections through student exchanges and shared teaching programs. The teaching program will be through a section that reaches across the entire ENAC School, taking full advantage of the depth and quality of our programs. The Center for Transportation and Mobility centered in ENAC (an EPFL-wide Center) is the model that we are using as we develop plans to implement, in parallel, a Center in Urban Systems Engineering within the next 12 months.

Follow-up in 2014

In 2012-2013, a strong effort was made to develop a new BS/MS teaching program called USE (Urban Systems Engineering). After many discussions and presentation in front of EPFL direction, preference was clearly shown for a MA rather than a BA/MA training.

In the meantime, ENAC hired Prof. Paola Vigano, expert in urbanism, and active in Architecture teaching, enriching the Master with a studio dedicated to urbanism, and compulsory for all the students in architecture.

In addition to this, Digital Sciences, and particularly Digital Humanities related to Venice, offers a new opening in ENAC for a Master in Digital Urbanism, a totally new concept to explore.

5. Institute for Architecture and the City

Audit findings and recommendations

It is likely that IA will need at least seven new faculty members over the next 3+ years, these appointments will set the directions of the Institute for several decades. The Committee also recognized the need to increase the breadth and diversity of faculty expertise into areas such as Landscape and Urbanism.

Response in 2011

We could not agree more with the Audit Committee on the need for renewal of professors in Architecture and have just concluded an international search for new faculty colleagues in Architectural Design. We are currently recruiting two new faculty colleagues in studio teaching, to begin fall semester 2012. We are anticipating further hiring to strengthen the Institute including positions in theory, history of architecture and construction; these are in the early stages of recruitment. Ongoing recruiting is underway with the plan to centrally support BS/MS teaching and further develop the PhD program. We maintain that the leadership in the Institute of Architecture is exemplary and conducive to full faculty engagement and international leadership in education and research.

Follow-up in 2014

IA has been able to hire 7 new faculty members in 2013. With Prof. Paola Vigano, the area of urbanism is fully considered.

6. Civil Engineering Institute

Audit findings and recommendations

The Committee would have liked to see examples of multidisciplinary projects and multidisciplinary use of the civil engineering laboratories. The Committee believes it is important for the Civil Engineering Institute to take a more outward looking view of its role within ENAC, including a commitment to multidisciplinary research with faculty in the other Institutes (IIE, IA and INTER).

Response in 2011

The Civil Engineering Institute is in many ways the core of our School; it has been pivotal in building links across ENAC and is central in the development of strategic programs in energy and urban systems engineering. We are grateful for the acknowledgement of the current outstanding professors and the remarkable quality of the professors we have been successful in recruiting in recent years. It should be noted the Institute was key to the establishment of the doctoral program in Civil and Environmental Engineering (EDCE) and the leadership in the doctoral program in Mechanics (EDME). Today, it is also responsible for the largest engineering section at EPFL. Faculty expansion in the coming years will be essential, including a refocusing of structural engineering, engineering mechanics, materials science, novel computational tools, lightweight structures, geotechnical and transportation engineering, and urban infrastructure planning. More generally, it is critical we continue to reinforce the fundamentals in which we educate our students and develop new basic knowledge through our research driven in part by applications. New faculty hires in Civil are key to the working fabric of ENAC in the coming years as discussed in the audit report.

Follow-up in 2014

IIC, with his new Director since the audit, Prof. J.-F. Molinari, has developed a new strategy, with plans for new positions to strengthen 4 core disciplines, to reach an attractive and visible critical mass. The point is not only to replace retirements but to increase the number of faculty members in IIC. This is key issue as the number of students is steadily increasing and opportunities of funding, such as CTI, are to be developed.

7. Environmental Engineering Institute

Audit findings and recommendations

ENAC has identified energy and urbanism as two grand challenges for the future. Faculty in the Environmental Engineering Institute must articulate how they will contribute and be a part of ENAC's response to these grand challenges of energy and urbanism. There should be more attention given to articulation of a strategy for integration with other institutes.

Response in 2011

We appreciate the acknowledgement of the excellent development of the Institute in recent years. We agree with the Audit Committee on the importance of the integration of Environmental Engineering professors with the rest of the School. This now takes place formally through our joint teaching initiative in Urban Systems Engineering and existing programs under the Projeter Ensemble umbrella. We note the positive comments regarding our development of joint research platforms and support center (e.g., the Central Environmental Laboratory). Environmental Engineering professors have played a leadership role in obtaining collaborative funding in the ProDoc and Sinergia programs of the SNSF and active leadership in the Landolt Chair and the Transportation Center among others, which draws on the full capacity that ENAC has to offer. The role of Environmental Engineering in ENAC will grow in the coming years through joint research and teaching programs.

In connection with major endeavors of the ENAC Faculty (specifically, Projeter ensemble and the now established yearly Semaine ENAC for junior undergraduates in Venice), ENAC is organizing the establishment of a nucleus of activities that blend together Architecture, Civil and Environmental Engineering, as inherent in its core mission. The initiatives will be centered in the city Venice (Italy), which is considered as a paradigm and central player in the crisis of modernity.

Follow-up in 2014

Although there is less urgency in developing the profile of IIE than IIC, the domain has a strong potential of collaboration and joint appointments with the ETH Domain research institutions.

In addition, the competition Solar Decathlon is an excellent example of a cementing activity for ENAC students, even reaching outside the School.

8. Student Enrollment

Audit findings and recommendations

The Committee believes that the teaching load associated with this uncontrolled increase of the student body puts significant additional pressure on the faculty and is counterproductive to the goal of pursuing excellence in research (especially at a time when there are major opportunities for ENAC). The Committee is also concerned that pressures associated with teaching loads can undermine the search process for outstanding faculty particularly within the Institute of Architecture and the City.

Response in 2011

Respectfully, we cannot agree with the impression of the Audit committee in this area. ENAC Professors have continually taken every opportunity to raise the academic standards in our teaching programs. We have increased the personal responsibility and expectations of the students, reduced formal contact hours to allow for more individual and group study, increased office hours for students to be able to 'drop in' and seek assistance, continually increased the demands for mastery of fundamentals of engineering and architecture design, and introduced more rigorous expectations and expanded integration of mathematics, computing, physics and chemistry in all classes. Originality in the Master projects is expected of all our students, and the opportunities to develop cross-disciplinary ENAC projects are whole-heartedly supported. The system in Switzerland is built on the premise that any student completing their gymnasium (high school) studies can enter EPFL, and we work to make certain that all our students can excel in their studies and that the first year is simply not an exercise in reducing student numbers. Many of our PhD students and post-doctoral associates serve as tutoring assistants each week in the core mathematics, physics and probability/statistics courses in the first two years of study. This has dramatically improved the core understanding of each student and lifted the academic standing of the student body. Finally, it should be noted the professional associations in Civil and Environmental Engineering regularly call for the education of more engineers for Swiss society at large, and we have the highest expectations for the knowledge and capacity for lifelong learning of each individual student.

Follow-up in 2014

In SAR the increase in teaching load has been slowed and has even slightly diminished. This is beneficial in terms of space, which is also a matter of concern. SGC is still growing, and the issues with teaching loads and space are still to be solved. SSIE has seen a decrease of enrollments, but the statistics since 1995 show that this variation is normal.

9. Projeter Ensemble

Audit findings and recommendations

The Audit Committee supports the “Projeter Ensemble” initiative (PE) as an excellent concept, and a distinguishing component of the educational programs within ENAC. The Audit Committee sees that further improvements in the PE program can be achieved through better internal diagnostics and more effective advanced planning for the projects.

Response in 2011

We appreciate the remarks from the Audit committee that the Projeter Ensemble initiative is an excellent concept and has been effective in energizing the faculty and students and raising their awareness of opportunities through integrated projects. We have started longer term planning of the projects (a year in advance) and have continued to increase broad faculty participation. We agree with the Audit Committee that there is limited physical space available for Projeter Ensemble and are working with the EPFL governance to address these space needs.

Follow-up in 2014

A recent evaluation has shown that SE and UE ENAC are not as transversal as they could be, and that there are too many external teachers involved in this teaching.

An effort is made to correct that tendency and to increase the internal teachers to participate, by means of incentives in teaching as well as in research projects.

10. Recherche Ensemble

Audit findings and recommendations

The Committee was very impressed by their meeting with a highly articulate group of students. However, it was surprising that none of the students in this group had done any research during their studies. The Committee believes this is a missed opportunity and that ENAC should investigate mechanisms for engaging undergraduate (BS/MS) students in research.

Response in 2011

We are pleased that the Audit Committee appreciated some of the fine examples of multi-disciplinary research programs that take place within ENAC (Lac Léman water quality project, multi-modal transport systems) and the quality of our students. Contrary to the impression made, however, first year students are already engaged in summer research programs throughout ENAC (including such multi-disciplinary research programs). Many of our students also obtain valuable experience in projects overseas in both developed and developing countries. In addition, we have numerous active collaborations that students throughout EPFL (e.g., BS & IC) can take benefit from, and we have many ENAC students active in leading “Ingenieurs du Monde” research projects. It is common for labs can have 5-10 students working during the semester and summer periods on research projects typically linked to PhD and postdoctoral projects. Finally, it is noted that all EPFL students have to formally complete a research project and thesis for completion of their MS. We suspect there might have been some uncertainty on the nomenclature for the Audit Committee regarding what constitutes a student research project at EPFL (e.g., a semester project is a formal method for students to gain credit as part of their studies in research, essentially all students take advantage of this opportunity offered in ENAC).

Follow-up in 2014

11. Gender and Diversity

Audit findings and recommendations

The Audit Committee recognizes the excellent efforts that have been made by the Dean of ENAC in addressing the issue of gender imbalance in the faculty over the last few years principally through Tenure-Track appointments.

Response in 2011

We agree fully on the importance of diversity and the sustained commitment necessary for the recruitment and retention of women faculty. Though we were not free to go into individual details with the Audit Committee, we have made strong efforts to increase the pool of outstanding women faculty candidates, to support dual careers, and to provide support for young women starting families. Indeed, the ENAC Direction is firmly committed to a sustained effort in this regard.

Follow-up in 2014

- The new Dean has set up two actions to support female recruitment.
- All Search Committee Chairs and the DirENAC, are asked to be more proactive in identifying potential good women in advance of new recruitments in ENAC
 - Creation of a Gender equality group, chaired by Prof. Rizlan Bernier-Latmani, to work in collaboration with Chairs of Search committees, helping to identify outstanding female applicants.

12. Audit Process

Audit findings and recommendations

The Audit committee finds that the audit process could have been improved.

Response in 2011

We agree that the Audit process could have been simplified and certain aspects clarified: 1) the pre-meeting coordination and planning should ideally have been entirely led by the School, 2) highlight future actions at each site visit presentation and 3) take more time to explain the operational aspects of the School.

Follow-up in 2014

**Evaluation of the School of Architecture,
Civil and Environmental Engineering (ENAC)
Site Visit, November 14-17, 2011**

**Report of the Audit Committee
December 23, 2011**

Introduction

The President of EPFL, Professor Patrick Aebischer appointed a committee of international experts (Appendix A) to review the teaching, research and long-term strategy of the School of Architecture, Civil and Environmental Engineering (ENAC). The committee was asked to assess the following five major issues (Appendix B):

- The achievements of ENAC, in relation to the objectives of the 2008-2011 EPFL Strategic Plan.
- The position of ENAC at national and international levels.
- The competence of ENAC's strategy in meeting the needs of society and contributing to the economy¹.
- The management and organization of ENAC.
- The implementation of recommendations made by the previous audit (June, 2006).

The leadership of ENAC prepared briefing materials for the committee including 1) a detailed self-evaluation report, 2) activity reports by ENAC faculty members, and 3) results of an alumni survey. Appendix C shows the schedule of meetings for the Audit Committee site visit, November 14-17. The review included general briefings by Dean Marc Parlange and the leadership of the 4 Institutes that comprise ENAC (Architectural, Civil, Environmental and Inter²), reports on the academic programs (BS&MS, Ph.D), tours of selected studios, research and teaching labs, presentations on specific programs

¹ This item has been paraphrased according to the interpretation of the committee.

² Institute of urban and regional sciences.

(TraCE, CEAT³) and meetings with groups of students (undergraduates and graduates) and junior faculty (Tenure Track [PATT]). The Committee would like to thank the leadership and faculty of ENAC for their hospitality during this intense site visit, for their extensive work in preparing briefing materials and for their candor and transparency in the meetings.

The Committee believes it is important to review ENAC in the context of the broader educational environment in Switzerland. The School operates under two particular constraints that are relatively unique: 1) there are no limits on the number of freshmen students matriculating each year in ENAC (or elsewhere at EPFL); and 2) the BS-MS programs in ENAC are required to provide professional qualifications for students to practice as Architects, Civil or Environmental Engineers (i.e., there is no further process of professional licensing outside of academia).

The Committee has tremendous respect for the visionary process that has transformed EPFL over the last ten years and understand that our review of ENAC must be interpreted in the context of a university system that is undergoing major change. Schools within EPFL must contend with legacy conditions, most notably the inheritance of a complex system of faculty appointments, while aspiring to the stature of a major international research university and ensuring excellence in educational programs.

Key Achievements of ENAC (2006-2011)

ENAC has clearly made very significant progress in the transformation process since the last audit in 2006. Under the leadership of a tremendously enthusiastic and committed Dean they have made a number of significant and notable achievements:

1. There has been significant advance in research productivity by ENAC faculty (in the aggregate) marked by increased scholarly output (leading archival journals, monographs and texts) and the level of research support over the period 2006-2010 (compared to 2002-2005).

³ TraCE – Transportation Center, CEAT - Urban and regional planning community.

2. New Ph.D programs (EDCE and EDME) within the CE and EE institutes are well organized and conceived, with appropriate admission standards and review procedures. Regular seminars and student-organized events contribute to a stimulating research environment.
3. The leadership of ENAC has been successful in recruiting a cadre of high caliber Tenure Track faculty (mainly Assistant Professors [PATT] – but also some notable senior and mid career appointments). The junior faculty members are well supported by excellent resources (access to facilities, funding for equipment and ability to recruit high quality research staff and students). They also report that there is a supportive collegial environment to help them build their careers.
4. The leadership of ENAC has been very effective in building productive collaborations with ETH Zone laboratories (notably EAWAG, WSL, PSL and EMPA). This has been accomplished principally through joint appointments.
5. ENAC has excellent facilities for research. The committee was especially impressed by the creation of centralized/shared research facilities in the Environmental Institute through the faculty renewal process.

Findings and Recommendations

Our Audit has generated the following recommendations for future directions of the School. The recommendations are based on the information received, and some may already be under consideration or implementation by ENAC.

1. Concept of ENAC

The original concept of ENAC brings together civil and environmental engineers with architects, urban scientists and planners. These academic communities represent diverse cultures and traditions, yet are united by their focus in addressing grand challenges of sustainable development, energy efficiency, resource conservation and environmental protection. The committee was impressed by the commitment of ENAC faculty to contribute in solving important societal problems. Inevitably ENAC is a complex heterogeneous organization whose long-term goals must bring together diverse scientists, engineers, architects, and social scientists. This is a unique experiment among leading

academic institutions (worldwide). The Audit committee believes it is important to endorse the concept of ENAC while recognizing that the School has much to do in order to fulfill its potential and the high aspirations of EPFL.

2. ENAC Strategy

The leadership of ENAC did not convey to the Audit committee a clear strategic plan for the next five-year period. Although the Self-Assessment Report (Vol. A) includes strategic objectives from each of the four Institutes, the Committee believes these should have been condensed to produce an ENAC plan with future trends, goals and prioritized actions. From our detailed discussions with the Dean, we understand there are three main research priorities: 1) establishing a leadership profile for energy-related research (anchored by ENAC work in the efficient use and conservation of energy in buildings and transportation systems, and development of renewable energy resources etc.); 2) developing expertise in urban engineering; and 3) establishing a Ph.D research community within the Architectural Institute. What is needed now is a realistic plan with clear actions for achieving the goals.

3. Management Structure

The Audit committee sensed that the management of ENAC would benefit from the Institute directors sitting together with the Dean and discussing the future of ENAC, the priority areas for investments and the means to achieve the future goals. The presentations during the three-day site visit gave the impression that each of the Institutes functions relatively autonomously in contrast to the integrative vision of ENAC. The Committee believes that more cooperation and collaboration amongst the Institutes is essential for the long-term health of ENAC.

4. Urbanism

The leadership of EPFL and ENAC place considerable emphasis on 'urban issues': Indeed, according to the 2012-2016 Development Plan EPFL should evolve into a

laboratory for contemporary urban planning (at both national and international scale). ENAC is clearly at the center of this activity and already encompasses expertise in urban sociology, transport and mobility, economics, environmental and risk management. The directors of the INTER Institute presented two alternative plans for introducing new BS/MS education programs in ‘Urban Sciences: Planning and engineering’. Members of the Committee expressed a number of concerns about these programs. In particular, they felt that ENAC has much greater strengths within engineering disciplines and hence, should focus initially on programs in urban engineering (i.e., problems of infrastructure systems). It will take longer to building capacity in broader dimensions of urban planning, beyond sociology and law.

The Audit Committee supports Urban Sciences as an integrating theme, but believes that new research and education programs should be developed through planning and participation of all institutes within ENAC (i.e., this should not be the sole/primary responsibility of a small unit such as INTER). We believe that this interaction is a pre-requisite process before identifying and prioritizing new faculty hires.

The Committee was encouraged by the initiation of multi-disciplinary research Centers, such as the Transportation and Mobility Center, TraCE, as a model for engaging faculty across Institutes within ENAC and between Schools. There appear to be other opportunities for similar Centers, for example linking existing research activities in risk management for natural hazards (across ENAC Institutes), and for ENAC leadership in renewable energy across EPFL.

5. Institute for Architecture and the City (IA)

The ‘Architectural Institute’ is in a period of major transition, with the expected retirement of several senior faculty, and at a crucial juncture. The leaderships of EPFL and ENAC have articulated their desire for a strong architecture program producing top quality research⁴.

⁴ We endorse the opinions of the 2006 Audit Committee regarding the metrics for evaluating research contributions in Architecture: *"The Institute of Architecture should consider other forms of evidence of peer review for architects, to be acceptable as equivalent to scientific referred journals such as publication*

The Architectural Institute has a strong design core that has attracted high caliber, international Visiting Professors over the last few years. The program is also experiencing unprecedented levels of student demand (more than 50% of ENAC BS students matriculate in IA). The faculty members are doing an excellent job managing the large intake (of first year students) and exposing them to a vibrant studio culture. There are active and growing research programs in the History and Theory of Architecture, and Construction and Building Science (aided by recent faculty hires). The Committee also supports the recent development of a new doctoral program for research in Design that will provide evidence to support areas of contemporary and current preoccupations in architecture ranging from digital and parametric design to craft-based techniques.

In order for the Architectural Institute to deliver research at a high international standard, the caliber of new faculty hires is of paramount importance. It is likely that IA will need at least seven new faculty members over the next 3+ years, these appointments will set the directions of the Institute for several decades. The Committee was disappointed to learn that an external search for a new Institute Director was unsuccessful. The recently appointed internal candidate must now formulate a coherent and compelling vision for the Architectural Institute if it is to attract high caliber core faculty.

The Audit Committee recommends that the ENAC leadership draw on its expertise in design (including the extensive external network of visiting Professors) to assist in attracting exemplary faculty who can lead design studios as a matter of urgency. The Committee also recognized the need to increase the breadth and diversity of faculty expertise into areas such as Landscape and Urbanism.

6. Civil Engineering Institute (IIC)

The Civil Engineering Institute received less attention during the Audit Committee site visit than the other constituents of ENAC. The Committee did not receive enough

of selected design proposals or built projects in named high level independent journals, selection in competitions, selection of projects in exhibition for the purposes of research and development of architecture."

information to develop a clear perspective on the Institute. The IIC Director's overview did not reflect the research strengths nor the multi-disciplinarity that is apparent in the Self Assessment Report (Vols. A & B) and gave little insight on new directions for research in civil engineering. However, the Committee recognizes that IIC has several researchers of international stature and has recruited a number of excellent faculty members since the 2006 Audit.

The Committee would have liked to see examples of multidisciplinary projects and multidisciplinary use of the civil engineering laboratories. The goals of tomorrow's energy needs and urban engineering are two areas where IIC should be an essential actor, but the plans for such interactions were not demonstrated. The Committee believes it is important for the Civil Engineering Institute to take a more outward looking view of its role within ENAC, including a commitment to multidisciplinary research with faculty in the other Institutes (IIE, IA and Inter).

7. Environmental Engineering Institute (IIE)

The Environmental Engineering Institute has recruited outstanding junior and senior faculty over the past five years. These faculty members are developing vibrant research programs that are recognized internationally for their excellence and a vision that addresses future environmental issues in four main domains: i) atmosphere and climate, ii) water and soil ecosystems; iii) waste and contamination; and iv) environmental modeling and monitoring. In this context they are renowned for state-of-the-art research in novel observational technologies, chemical and microbiological processes, and environmental measurements.

The Institute has articulated its strategic objectives for 2011-2016, as (Self-Assessment Report p39): *"Building a coherent common theme for IIE centered on the definition and operational pursuit of sustainable development and the understanding and control of the co-evolution of the built and the natural environments. (p. 39)"*

This is a commendable goal, however, achieving it will require articulation of a coherent strategy for collaboration and coordination that makes the whole greater than the sum of

its parts. It is not sufficient for individual faculty in IIE to focus exclusively on their own laboratory's research program.

ENAC has identified energy and urbanism as two grand challenges for the future. Faculty in the Environmental Engineering Institute must articulate how they will contribute and be a part of ENAC's response to these grand challenges of energy and urbanism. Responding to these challenges will not only require coordination among the faculty within IIE, but more importantly will call for integration with the other ENAC institutes (IA, IC, INTER). There should be more attention given to articulation of a strategy for integration with other institutes.

8. Student Enrollment

The Audit Committee realizes that EPFL as a whole has experienced a tremendous growth in number of students in recent years (2006 to 2011). This is true in particular for ENAC with a total of 1534 BS and 459 MS students in 2011 (in the three study programs Architecture, Civil and Environmental Engineering). It is particularly noteworthy that in the same period, the number of Freshmen has grown from 262 to 517, and that a large percentage (approx. 50%) of these students do not make it to the second year. Nonetheless, the result is a significant growth of the total student body, most notably in the Architecture program.

The Audit Committee senses a reluctance of the ENAC leadership to take control of the size of the student body entering the second year. The Committee believes that the teaching load associated with this uncontrolled increase of the student body puts significant additional pressure on the faculty and is counterproductive to the goal of pursuing excellence in research (especially at a time when there are major opportunities for ENAC). The Committee is also concerned that pressures associated with teaching loads can undermine the search process for outstanding faculty particularly within the Institute of Architecture and the City.

ENAC should not miss this opportunity to raise the general academic standards of its student body at a time when the applicant pool is growing. The Committee recommends

that steps should be taken to assess the size of a sustainable student body and to institute measures to maintain this.

The large fluctuations in the numbers of first year students present a significant problem for the management of ENAC (faculty resources, space etc.). This is clearly where the School needs more help from EPFL pending more general (university-wide) changes in the first year (propaedeutic) curriculum.

9. Projeter Ensemble

The Audit Committee supports the “Projeter Ensemble” initiative (PE) as an excellent concept, and a distinguishing component of the educational programs within ENAC. PE has clearly been effective in energizing the faculty and students and raising their awareness of opportunities through integrated projects. The program appears to enjoy broad support among ENAC faculty and students.

The Audit Committee sees that further improvements in the PE program can be achieved through better internal diagnostics and more effective advanced planning for the projects. The Committee also recommends that ENAC exchanges experience with other universities that have adopted similar initiatives.

At present there is limited physical space available for Projeter Ensemble – with architects and engineers working in different buildings. The success of these programs will be greatly enhanced if the project teams are able to work together in a common space. We believe ENAC should further develop the aspiration, and articulate the extent to which it can be realized.

10. Rechercher Ensemble

One recurring theme throughout the site visit was the lack of communication and collaboration among faculty in the four Institutes of ENAC. Indeed, there is a major challenge to bring together disparate communities of architects, engineers, scientists, social scientists etc. Although Projeter Ensemble is effective in bringing together the faculty for short educational projects, much more needs to be done to bring the research

cultures together. The Committee heard two good examples of multi-disciplinary research programs – one a special summer program covering a range of environmental measurements and impacts of pollutants in the waters and sediments of Lac Leman, the other, a flagship proposal to study new multi-modal transport systems. These types of large multi-disciplinary research programs offer the opportunities needed for integration of research across ENAC.

The Committee was very impressed by their meeting with a highly articulate group of students. However, it was surprising that none of the students in this group had done any research during their studies. The Committee believes this is a missed opportunity and that ENAC should investigate mechanisms for engaging undergraduate (BS&MS) students in research. By sharing the excitement of knowledge discovery, the best and brightest students will be inspired to pursue doctoral studies.

11. Gender and Diversity

The Audit Committee recognizes the excellent efforts that have been made by the Dean of ENAC in addressing the issue of gender imbalance in the faculty over the last few years principally through Tenure Track appointments. The Dean has described the recruitment of the strongest professors internationally as one of his most important priorities. Four of the 10 Tenure Track faculty appointments in ENAC are women. With women now accounting for almost 40% of the Ph.D population in ENAC this is clearly a step in the right direction but will require a sustained commitment from the leadership of ENAC both in the recruitment and retention of women faculty.

12. Audit Process

The Audit committee finds that the audit process could have been improved through the following:

- The questions to the audit committee should have been better coordinated. The Committee was given three different (and somewhat contradictory) sets of

questions to address (in the cover letter of appointment, in the formal terms of reference and in the introductory presentation by the President of EPFL).

- The presentations at the site visit presentations should have provided a status report or referenced the evaluation questions. The committee would have been helped with a concise and focused list of future actions, the means of creating a shared vision and goals, the follow-up to recommendations from the 2006 Audit, and details on how the links between the technological sciences, social sciences and humanities are achieved in practice.
- The Audit Committee expected that the presenters from the different Institutes would have been given more guidance on what to communicate, that the presentations should have had similar format, and that the written strategies in the Self Evaluation Report should have been condensed to produce an ENAC plan with future trends, goals and prioritized actions. The Audit committee finds that there was not enough communication among the Institutes during the preparation of the audit.

Respectfully submitted to Professor Patrick Aebischer, President of EPFL by:

Prof. Peter Ache, Aalto University Foundation, Finland

Prof. Yves Crozet, Université de Lyon II

Prof. Katharine Heron, University of Westminster

Dr. Suzanne Lacasse, Norwegian Geotechnical Institute (NGI), Oslo

Prof. Carlo Ratti, Massachusetts Institute of Technology

Prof Brigitte Shim, University of Toronto

Prof Soroosh Sorooshian, University of California at Irvine

Prof Henrik Stang, Technical University of Denmark

Prof. Albert Valocchi, University of Illinois, Urbana-Champaign

Prof. Andrew Whittle, Massachusetts Institute of Technology (Chair)

Survey on the professional integration of EPFL Master graduates 2013-2016

Career Centre EPFL

(Situation on 28 November 2018)

- 1 Master of Science in Architecture
- 2 Master of Science in Civil Engineering
- 3 Master of Science in Environmental Science and Engineering

1. Master of Science in Architecture

1.1 Place of residence of graduates

	Number	Percentage
Switzerland	129	84.9
Outside Switzerland	23	15.1
Total:	152	100.0

1.2 Activities after one year

	Number	Percentage
Employed	119	78.3
Independent	17	11.2
PhD	3	2.0
Searching for a job	9	5.9
Unemployed, not searching	4	2.6
Total:	152	100.0

1.3 First employer (graduates in employment, 1.2 above)

	Number
Herzog & de Meuron	4
Ferrari Architects	4
Pont 12 Architects	3
Jaccaud Spicher Architects	3
A Carré Architecture	2
Andrey & Barthassat Architects	2
Bauart Architects and Urbanists	2
CCHE	2
Dolci Architects	2
Grimshaw Architects	2
Canton of Fribourg	2
Other	91
Total:	119

1.4 Host university (doctoral graduates 1.2. above)

	Number
EPFL	3
Total:	3

1.5 Average hiring salary in Switzerland (graduates, 1.2 above)

	Women	Men	Overall	EPFL
Number of replies	44	50	94	755
Average salaries (CHF)	60,983	65,257	63,256	77,722

Note: Not all replies reported salary

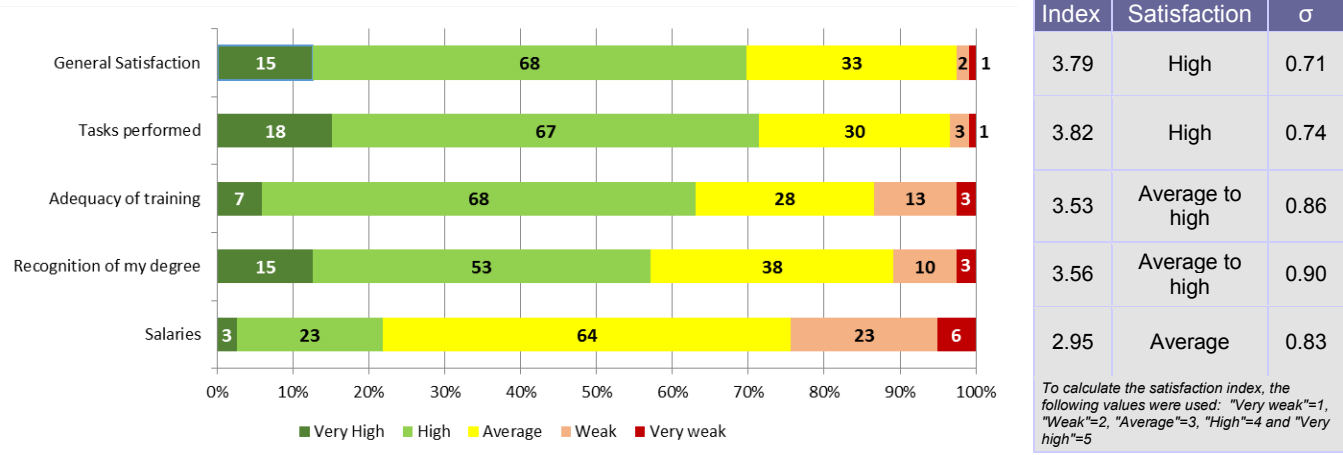
1.6 Job search effort (graduates 1.2 above)

	Architecture	EPFL
Average number of candidacies	15	15
Average number of job offers	1.7	1.6
Number of weeks of job search	7.9	11.5

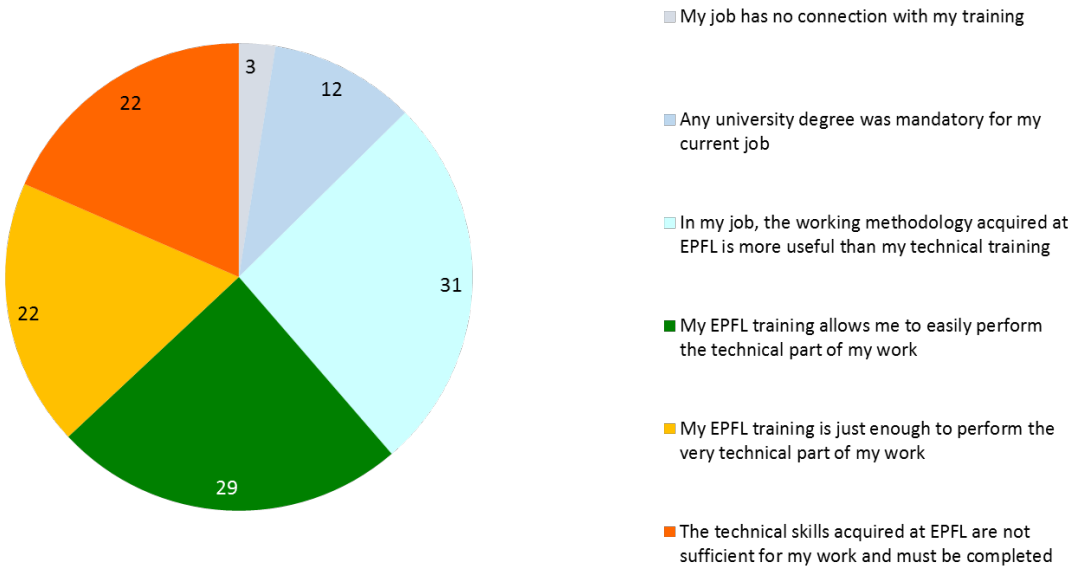
1.7 Job function according to the EPFL standard categories (graduates 1.2 above)

Functions	Number
Architect/Civil engineer/Environmental engineer	111
Architect/develop computational solutions	1
Project Management	1
Teacher/Lecturer	1
Other function	5
Total:	119

1.8 Satisfaction at work (graduates in employment 1.2 above)



1.9 Competencies acquired at EPFL compared to the requirements of the current position



2. Master of Science in Civil Engineering

2.1 Place of residence of graduates

	Number	Percentage
Switzerland	97	78.9
Outside Switzerland	26	21.1
Total:	123	100.0

2.2 Activities after one year

	Number	Percentage
Employed	107	87.0
Independent	2	1.6
PhD	8	6.5
Searching for a job	2	1.6
Unemployed, not searching	4	3.3
Total:	123	100.0

2.3 First employer (graduates in employment 2.2 above)

	Number
Emch+Berger	6
Bonnard & Gardel (BG)	3
CSD Consulting Engineers	3
B+S Consulting Engineers	3
Citec	3
Groupe Bouygues	2
AB Engineers	2
Boston Consulting Group	2
CFF	2
Implenia	2
Karakas & Français	2
MP Consulting Engineers	2
Other	75
Total:	107

2.4 Host university (doctoral graduates 2.2. above)

	Number
EPFL	7
University of California Berkeley	1
Total:	8

2.5 Average hiring salary in Switzerland (graduates 2.2 above)

	Women	Men	Overall	EPFL
Number of replies	16	68	84	755
Average salaries (CHF)	78,694	79,488	79,336	77,722

Note: Not all replies reported salary

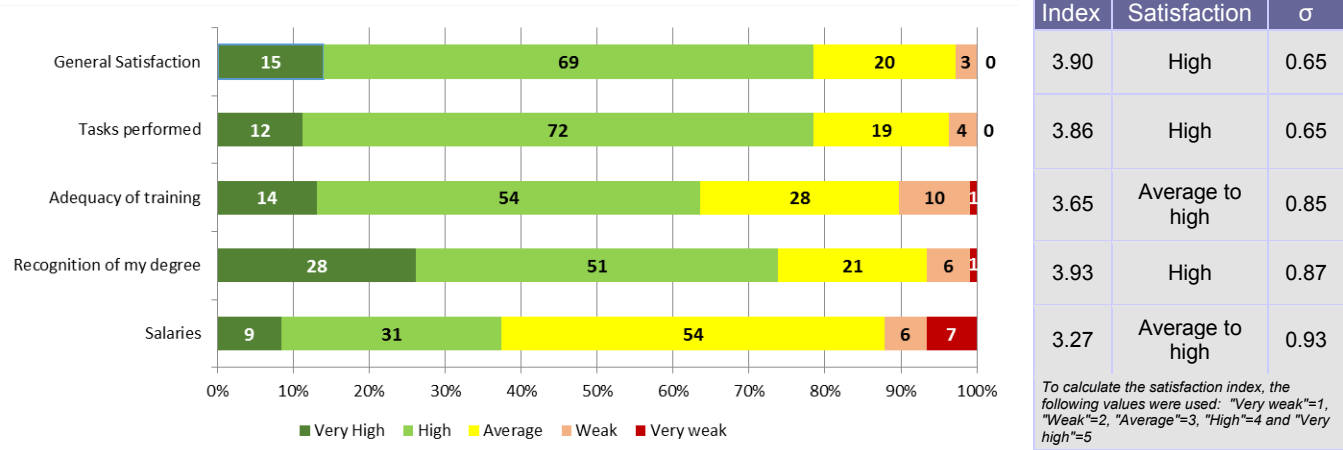
2.6 Job search effort (graduates 2.2 above)

	Civil Engineering	EPFL
Average number of candidacies	10	15
Average number of job offers	1.9	1.6
Number of weeks of job search	9.6	11.5

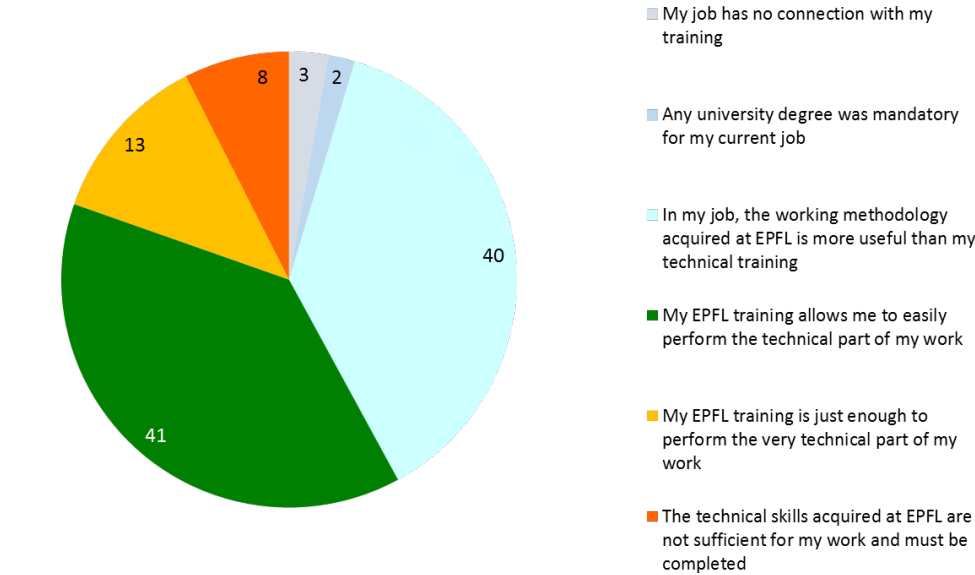
2.7 Job function according to the EPFL standard categories (graduates 2.2 above)

Functions	Number
Architect/Civil Engineer/Environmental Engineer	71
Consultant (all domains)	10
Project manager	10
Business analyst	5
Other function	11
Total:	107

2.8 Satisfaction at work (graduates in employment 2.2 above)



2.9 Competencies acquired at EPFL compared to the requirements of the current position



3. Master of Science in Environmental Sciences and Engineering

3.1 Place of residence of graduates

	Number	Percentage
Switzerland	68	73.9
Outside Switzerland	24	26.1
Total:	92	100.0

3.2 Activities after one year

	Number	Percentage
Employed	60	65.5
Independent	3	3.3
PhD	10	10.9
Searching for a job	10	10.9
Unemployed, not searching	9	9.5
Total:	92	100.0

3.3 First employer (graduates in employment 3.2 above)

	Number
CSD Consulting Engineers	6
Cantonal offices	4
Confederation (non EPFL/ETHZ)	2
Pix4D	2
Other	46
Total:	60

3.4 Host university (doctoral graduates 3.2. above)

	Number
EPFL	7
University of British Columbia	1
Tufts University	1
TU Denmark	1
Total:	10

3.5 Average hiring salary in Switzerland (graduates 3.2 above)

	Women	Men	Overall	EPFL
Number of replies	21	20	41	755
Average salaries (CHF)	70,791	69,509	70,166	77,722

Note: Not all replies reported salary

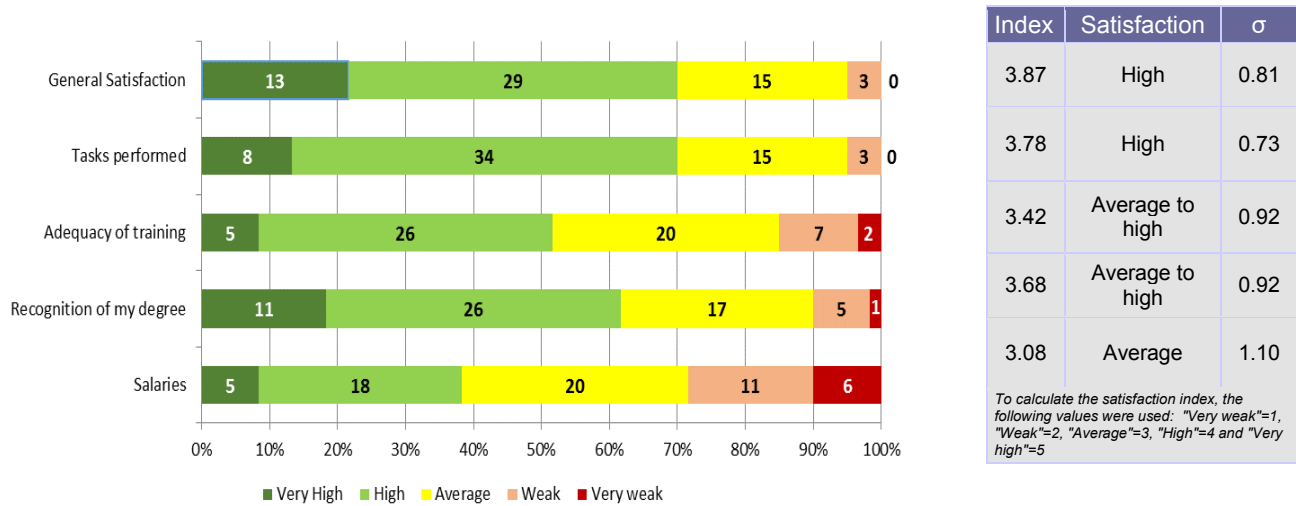
3.6 Job search effort (graduates 3.2 above)

	S.I.E.	EPFL
Average number of candidacies	17	15
Average number of job offers	1.5	1.6
Number of weeks of job search	11.2	11.5

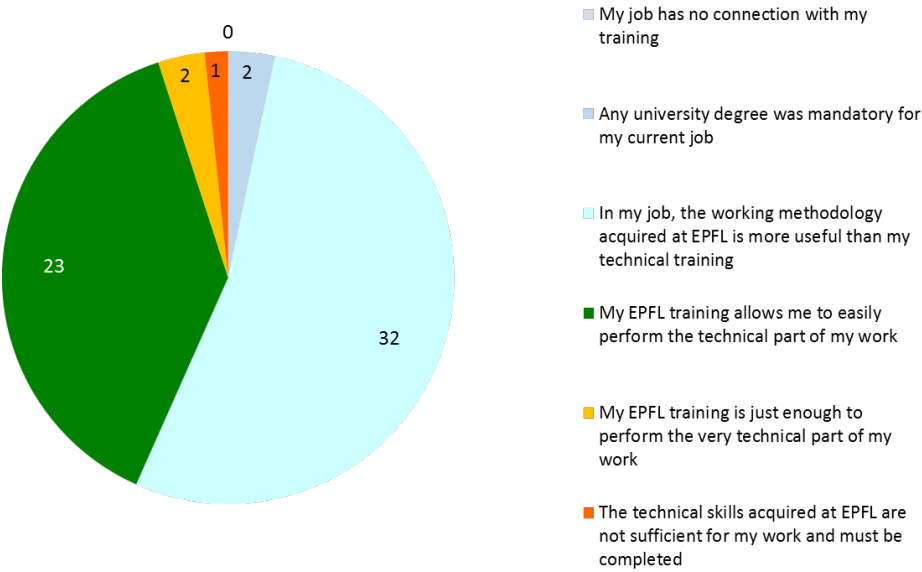
3.7 Job function according to the EPFL standard categories (graduates 3.2 above)

Function	Number
Architect/ Civil engineer/Environmental engineer	35
Project manager	6
R&D engineer	4
Consultant (all domains)	3
Other function	12
Total:	60

3.8 Satisfaction at work (graduates in employment 3.2 above)

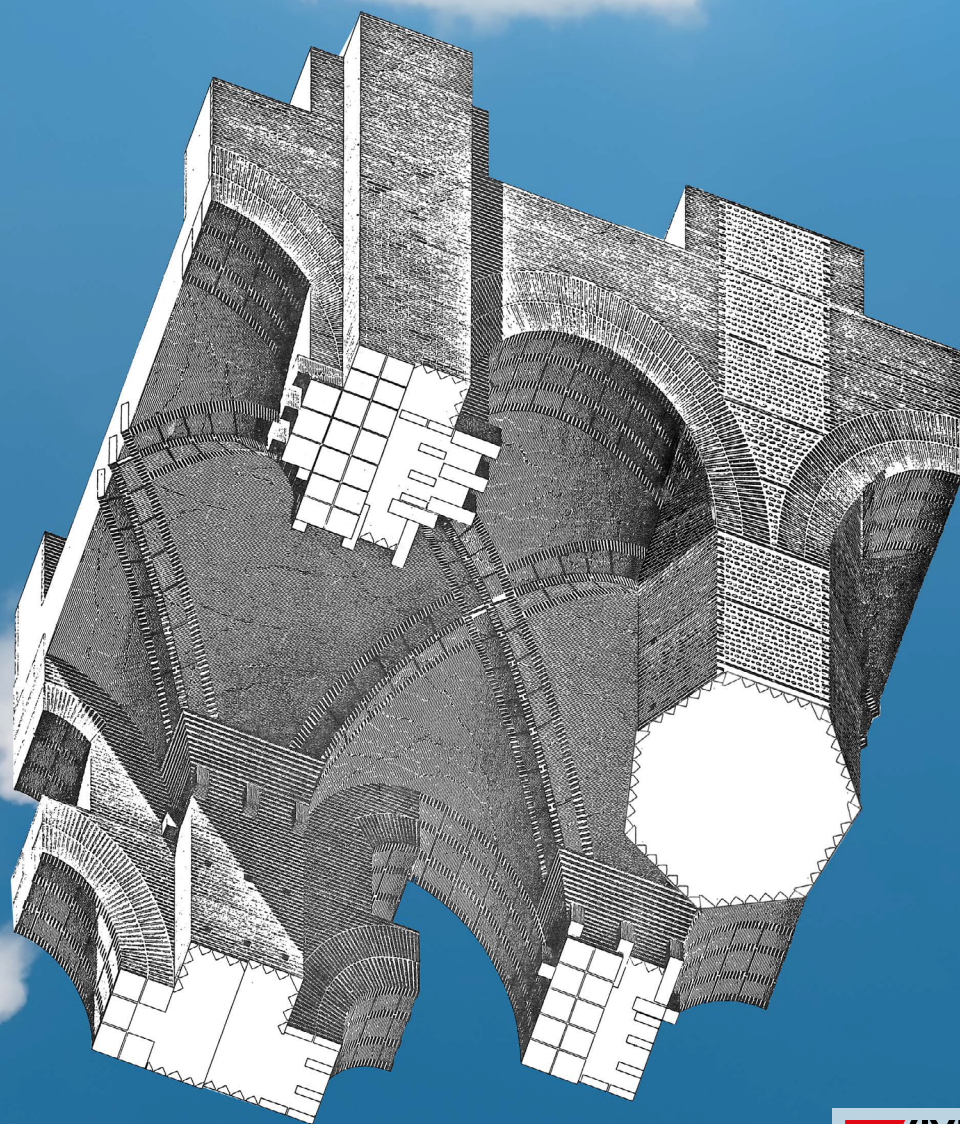


3.9 Competencies acquired at EPFL compared to the requirements of the current position



ARCHITECTURE

BACHELOR



On y vit,
on y travaille,
on y apprend,
on s'y distrait, on y meurt aussi.
Les constructions humaines sont à l'image de
ceux qui les imaginent et les habitent: diverses.

Elles sont dès lors le fruit de préoccupations
et de volontés techniques, sociales, pratiques,
esthétiques, culturelles, économiques et
de façon croissante, environnementales.

Construire les bases

Apprendre, penser, agir

Grâce à son cursus, la section d'architecture (SAR) forme ses étudiants afin que ceux-ci deviennent des professionnels exigeants, efficaces, mais également capables de s'adapter aux évolutions de la société.

Voir la vidéo :



Anne Fanny : « Ce qui me plaît vraiment dans un projet, c'est imaginer les espaces que je fabrique, penser que des gens peuvent s'y promener et s'y sentir bien. »

Pendant les trois ans que dure le bachelor, les étudiants acquièrent les bases de la discipline grâce à une série de cours qui couvrent l'essentiel des principaux domaines de la discipline.

La formation de base qu'est le bachelor, tel que défini par les accords de Bologne, dure trois ans, soit six semestres. Durant la première année, les étudiants doivent suivre les classiques enseignements propédeutiques, on serait tenté de dire, les fondations.

Puis viennent les finitions, tout aussi importantes, faites de théorie et d'histoire de l'architecture, de l'étude de la construction et des technologies durables, de l'art et de l'expression architecturale, de l'urbanisme et des sciences sociales. Cette richesse est augmentée par des enseignements pluridisciplinaires dispensés par des spécialistes en architecture bien sûr, mais aussi en ingénierie civile et en sciences et ingénierie de l'environnement.

Pendant cette période du bachelor, les étudiants architectes auront l'occasion de croiser des jeunes d'autres sections lors de cours communs, notamment en sciences humaines et sociales.

Elargir ses horizons

Si le bachelor est l'occasion d'acquérir une grande partie du bagage théorique et pratique du futur architecte, il se conclut par une nécessaire et enrichissante plongée dans la réalité professionnelle.

A l'issue de son bachelor, l'étudiant doit réaliser un stage pratique de douze mois. Cette condition *sine qua non* pour être admis au niveau du master, est une occasion très profitable de confronter ses premiers acquis théoriques à la pratique et de cimenter son savoir.

L'architecte en formation peut ainsi aiguiser ses connaissances dans certains domaines plus concrets comme la gestion de projet, la conduite de travaux, mais aussi les aspects financiers, et ils sont nombreux – ou encore le développement et la planification. Il ne faut pas non plus

Raphaël Bach : « J'aimais une variété de domaines, à la fois artistiques et techniques. Et je pense que l'architecture est le métier avec la plus belle symbiose entre tous ces aspects de la réflexion. »

Voir la vidéo :



© Alain Herzog

Learning by doing

L'étudiant peut enrichir ses connaissances pratiques et son expérience par d'autres moyens que les cours. Il dispose d'une place en atelier ainsi que d'un accès à une riche bibliothèque spécialisée.

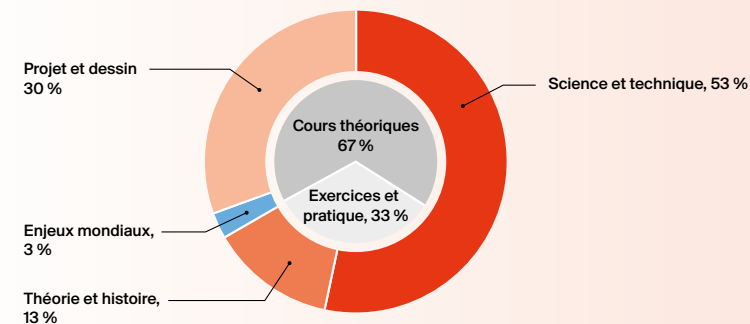
Une idée naît dans un esprit. Elle peut ensuite prendre forme sur un écran par l'entremise d'un logiciel 3D. Elle peut aussi naître au bout des doigts par la réalisation d'une maquette. C'est un exercice que continuent de pratiquer nombre d'architectes malgré les progrès réalisés par les techniques de rendu virtuel.

Les étudiants ont à leur disposition une place de travail en atelier. Ils peuvent profiter des infrastructures de l'atelier des maquettes, mais également des imprimantes pour les dessins, ou leurs créations de volumes modélisés directement en 3D.

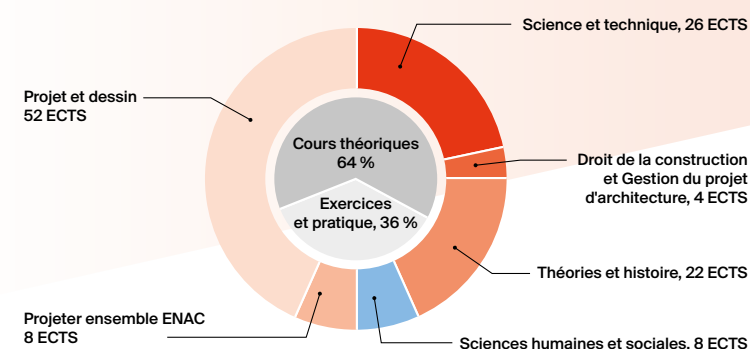
La bibliothèque d'architecture se situe dans le Rolex Learning Center. Tous les ouvrages y sont bien évidemment en libre accès.

Pendant toute la durée de leurs études, les étudiants peuvent recevoir des conseils particuliers de la part du corps enseignant notamment lors des séances d'exercices. Ils peuvent aussi compter sur les conférences et les expositions pour parfaire leur formation.

Plan d'études Bachelor 1^{re} année



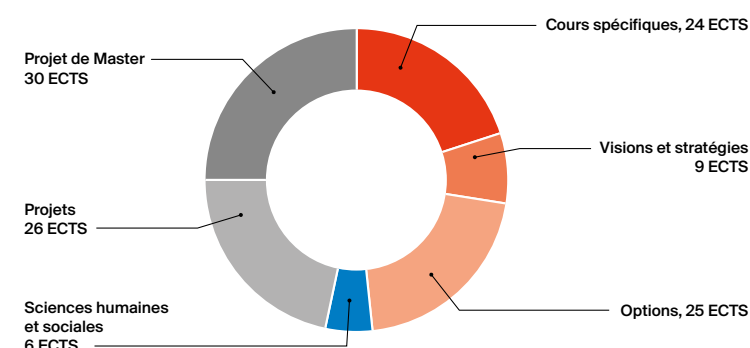
Bachelor 2^e et 3^e années



- 10 exemples de cours :**
- Concevoir des structures
 - Construction et durabilité
 - Droit de l'architecte, introduction : contrats et concours
 - Figuration expressive
 - Histoire de l'architecture
 - Histoires de l'environnement
 - Physique du bâtiment
 - Technologie du bâti
 - Théorie de l'architecture
 - Théories de l'urbanisme

La formation comprend un stage obligatoire d'une année entre le Bachelor et le Master.

Master (120 crédits ECTS)



- Orientations proposées :**
- Art et architecture
 - Construction, matériaux et ressources
 - Forme et type(s)
 - Logement collectif
 - Projet urbain
 - Sauvegarde et patrimoine

- Mineurs possibles (30 ECTS) dans le cadre des options :**
- Développement territorial et urbanisme (DTU)
 - Mineur Interdisciplinaire en Design Intégré, Architecture et Durabilité (IDEAS)

PERSPECTIVES PROFESSIONNELLES

Si les études d'architecture mènent naturellement à exercer la profession d'architecte, elles offrent également de nombreuses possibilités liées à ce métier, ainsi que d'autres débouchés moins attendus.

Architecte indépendant ou associé. Projeteur dans un bureau. Fonctionnaire dans une administration publique en relation avec le bâti (conservation du patrimoine, aménagement du territoire et du paysage, urbaniste, etc.). Scénographe (spectacles ou expositions). Gestionnaire de projets. Logisticien. Délégué à un projet humanitaire. Gestionnaire immobilier. Expert immobilier. Chercheur. Enseignant. Professeur. Editeur.

Pour plus d'informations: bachelor.epfl.ch

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Section d'architecture

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GÉNIE CIVIL

BACHELOR

Pont de la Poya © Service des ponts et chaussées, Etat de Fribourg



© Alain Herzog

De tout temps,
le génie civil a imaginé et
construit les infrastructures nécessaires
au bien-être et à la protection des hommes.
Les réseaux de transports et d'énergie
sont plus complexes, les constructions plus
audacieuses, les matériaux plus variés,
mais la mission demeure :
« Etre créatif pour offrir des équipements et
systèmes de très haute qualité ».

Diversité

En plus de jouer un rôle central dans le développement des sociétés modernes, le génie civil offre une rare diversité puisqu'on y traite aussi bien de structures, d'hydraulique, d'énergie, de géotechnique, de transports, de mobilité, de stockage, de risques ou encore d'environnement. A cette variété de domaines, s'ajoute d'une part celle des matériaux, des sciences et des techniques qui y sont utilisés et d'autre part celle des rôles que l'ingénieur en génie civil peut y jouer qui vont de la conception à l'exploitation en passant par la réalisation. De quoi se mettre à l'abri de la routine.

Christof Frutiger : « Les études sont très bien structurées et les profs supers. Au début, l'accent est mis sur les cours de base, mais très vite, la matière devient plus concrète. D'ailleurs, c'est ça qui m'a plu dans le génie civil: construire quelque chose dont on pourra voir le résultat après. Pour le Master, je vais me spécialiser en hydraulique : c'est un domaine nécessaire pour le futur. »

Agir sur l'existant

L'art de l'ingénieur civil s'exerce toujours plus sur des ouvrages existants. Des opérations de maintenance qui se conjuguent fréquemment avec des opérations d'amélioration des structures. A l'instar de ce que vit actuellement la Suisse dans le domaine de l'optimisation énergétique des bâtiments. Pour modifier intelligemment des objets existants, il est impératif de d'abord comprendre comment ils ont été conçus et comment ils fonctionnent. Une démarche qui implique un travail d'investigation souvent passionnant.

Leda Calgeer : « Je me suis toujours intéressée aux bâtiments, à comment ils sont construits. Et ce qui était important pour moi, c'était vraiment cet aspect technique. »

Voir la vidéo :



La formation

La formation en génie civil de l'EPFL permet à nos étudiants d'acquérir les connaissances qui leur permettront d'élaborer des projets de grande envergure mais également d'en conduire la réalisation. Les trois premières années d'études privilégient l'acquisition des bases nécessaires à la compréhension des concepts, à la maîtrise des techniques de construction, à l'évaluation de ces techniques et à leur intégration dans notre environnement naturel et construit.

3^e pont sur le Bosphore © T engineering SA



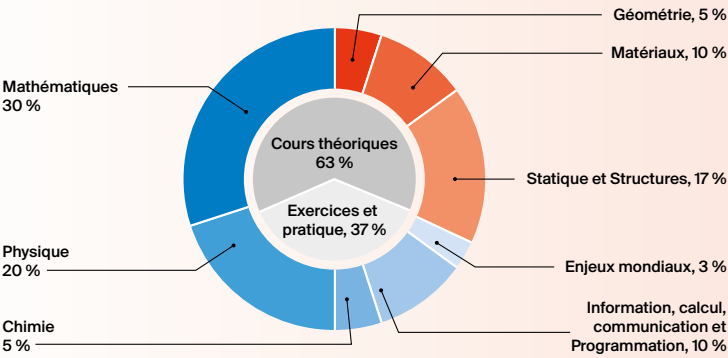
© AlpTransit Gotthard AG

Science de l'équilibre

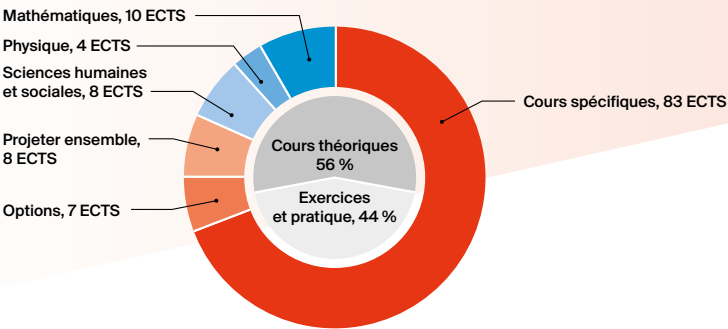
Un des rôles clés de l'ingénierie civile consiste à choisir et comprendre le comportement structurel des ouvrages. Pour un bâtiment ou un pont, il s'agit de définir les charges puis d'assurer leur cheminement de leur point d'application jusqu'aux fondations. Les efforts dans la structure sont ensuite calculés pour déterminer les dimensions des différentes parties de l'ouvrage de façon à respecter des critères de résistance et de déformabilité des matériaux qui les composent.



Plan d'études Bachelor 1^{re} année

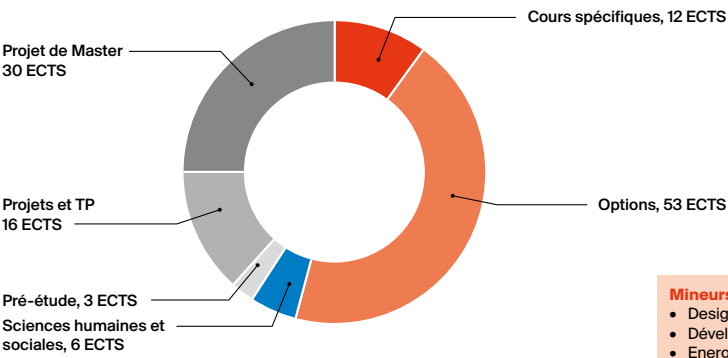


Bachelor 2^e et 3^e années



- 10 exemples de cours spécifiques/à option :**
- Conception et gestion des systèmes de transport
 - Conception des ponts
 - Étude et analyse des systèmes énergétiques
 - Mécanique des roches et ouvrages souterrains
 - Modélisation numérique des solides et structures
 - Ouvrages et aménagements hydrauliques
 - Ouvrages géotechniques
 - Sécurité et fiabilité
 - Structures en béton
 - Informatique (pour GC)

Master (120 crédits ECTS)



- 46 cours à option répartis dans les 4 spécialisations suivantes :**
- Géotechnique
 - Transport et Mobilité
 - Ingénierie structurale
 - Hydraulique et Énergie

Le Master comprend un stage obligatoire en entreprise.

- Mineurs possibles (30 ECTS) dans le cadre des options :**
- Design Intégré, Architecture et Durabilité
 - Développement territorial et urbanisme
 - Énergie
 - Management de la Technologie et Entrepreneuriat
 - Science et ingénierie computationnelles

PERSPECTIVES PROFESSIONNELLES

Du fait de la demande accrue en ingénieurs hautement qualifiés dans le domaine de la construction en Suisse, les perspectives professionnelles pour nos étudiants sont excellentes. Les bureaux d'études en génie civil, les administrations et les entreprises de construction en sont les employeurs privilégiés. Toutefois, les compétences scientifiques et la polyvalence de nos ingénieurs leur permettent aussi de se diriger vers des activités professionnelles très diversifiées. Quelle que soit la voie choisie, vous aurez à collaborer avec de nombreux partenaires issus des domaines de l'architecture, de l'environnement, de la sociologie, de l'économie, des milieux énergétiques ou encore de la politique. Très apprécié à l'étranger, le savoir-faire des ingénieurs civils suisses vous autorise en outre à envisager une carrière internationale.

Pour plus d'informations: bachelor.epfl.ch

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SCIENCES ET INGÉNIERIE DE L'ENVIRONNEMENT

BACHELOR



Vous vous intéressez au développement durable, à la qualité de l'eau, aux flux des déchets, aux problèmes des émissions polluantes ou des sites pollués ?
Les énergies renouvelables vous passionnent ainsi que les questions liées aux changements climatiques, aux dangers naturels et à leur prévention ?
Vous voudriez maîtriser les techniques d'acquisition et d'analyse de données spatiales, développer des réseaux de capteurs destinés à l'environnement ?
Alors la formation SIE et ses perspectives professionnelles vous séduiront.



Des bases solides

Le cycle bachelor offre à l'étudiant une formation propédeutique consistante. De quoi faire la différence quand on travaille à rendre un monde plus durable.

L'ingénieur SIE possède une double formation. C'est un scientifique qui sait décrire et expliquer les modifications de l'environnement causées par sa propre dynamique et par les activités humaines; mais c'est aussi un ingénieur qui conçoit et applique les techniques de pointe les plus appropriées pour éviter, atténuer ou remédier aux effets négatifs de ces activités.

Il acquiert l'essentiel des bases scientifiques en mathématiques, chimie, physique, biologie et informatique au cours des deux premières années d'études, fondement des cours plus spécifiques dédiés aux nombreux aspects des sciences et ingénierie de l'environnement.

Comme les enjeux environnementaux possèdent invariablement des aspects juridiques, politiques, économiques, sociaux et culturels, des cours dans les domaines des sciences humaines, du droit et du concept de « projeter ensemble » sont intégrés dans la formation SIE.

Voir la vidéo :



Gianluca Paglia :

« Cette formation nous permet de comprendre, de tous les points de vue, l'impact de l'homme sur la nature et l'impact de la nature sur l'homme. »



Au cœur des enjeux

L'ingénieur en environnement est souvent responsable d'un projet environnemental transdisciplinaire.

La renaturation des cours d'eau est une opération complexe, de plus en plus encouragée par les autorités politiques pour favoriser la biodiversité, qui exige le concours de plusieurs spécialistes : biologistes, géologues, urbanistes, ingénieurs en environnement, ONG et autorités locales.

Préparé à l'interdisciplinarité, l'ingénieur SIE n'éprouve pas de difficultés à réaliser des incursions dans des domaines connexes pour dégager un consensus, clé de la réussite de ce genre de projet.

La dépollution des sites industriels nécessite un travail d'investigation pour connaître l'origine des contaminations (historique du site, exploitation). Ce genre d'enquête caractérise aussi le domaine de la gestion des ressources, quand l'ingénieur doit effectuer des évaluations spatio-temporelles, notamment pour établir des prévisions. Dans les deux cas, les systèmes d'information géographique, de modélisation et de simulation offrent une aide précieuse pour tester les solutions préconisées et estimer l'évolution future de la situation.

L'innovation durable

Le développement technologique stimule la créativité des ingénieurs SIE et les pousse à utiliser et adapter une large variété d'outils informatiques afin de résoudre les défis qu'ils affrontent.

Outre ses capacités à développer des modèles et à réaliser des simulations de processus, l'ingénieur SIE fait équipe avec ses collègues informaticiens ou de systèmes de communication pour concevoir, produire et programmer des capteurs communicants pour le monitoring de l'environnement. Ainsi, des outils innovants tels que le Sensorscope se révèlent utiles dans la prévision des inondations. Quant aux lasers LIDAR et caméras à haute résolution qui équipaient les ULM pour l'étude des couches superficielles du Léman ou du lac Baïkal, ils permettent l'analyse de processus environnementaux complexes et le suivi de ces milieux aquatiques en exploitant de nombreuses données dans des systèmes d'information géographique.

Maîtrisant ces technologies de l'information, l'ingénieur SIE les appliquera dans les multiples domaines de l'environnement.

Enjeux mondiaux, problèmes locaux

L'ingénieur SIE est-il voyageur ?

Ses interventions seront appréciées jusqu'aux contrées les plus lointaines.

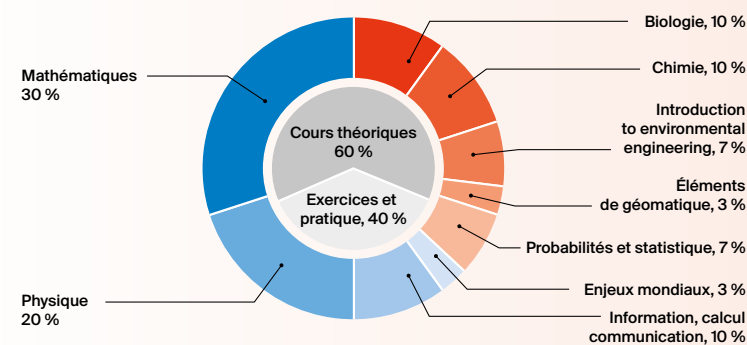
Nombre d'étudiants ou de diplômés SIE partent au bout du monde pour apporter leur expertise. Dans le domaine de la gestion de l'eau notamment, un domaine d'importance grandissante tant les pressions sur cette ressource vitale augmentent, certains adaptent un modèle hydrologique suisse aux zones inondables d'un fleuve

asiatique et aident les décideurs locaux à visualiser les impacts de futures centrales hydroélectriques. D'autres en Afrique ou en Amérique latine gèrent la construction de réseaux d'adduction d'eau ou de récupération des eaux de pluie, et ceci en étroite collaboration avec les autorités locales.

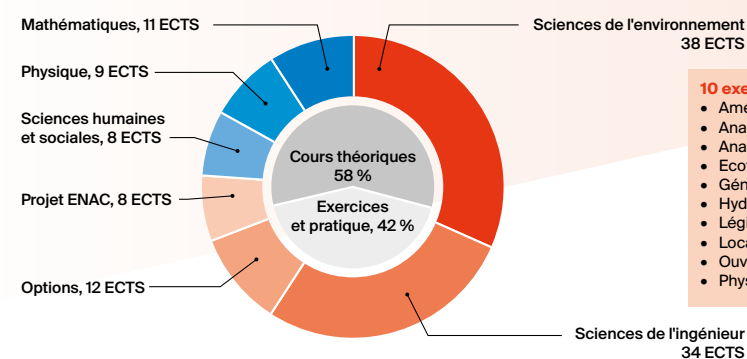
Ces projets exigent non seulement une solide formation d'ingénieur, mais surtout un grand sens de l'adaptation, de la négociation et de la communication pour proposer et mettre en place des solutions durables appropriées au contexte du pays.



Plan d'études Bachelor 1^{re} année



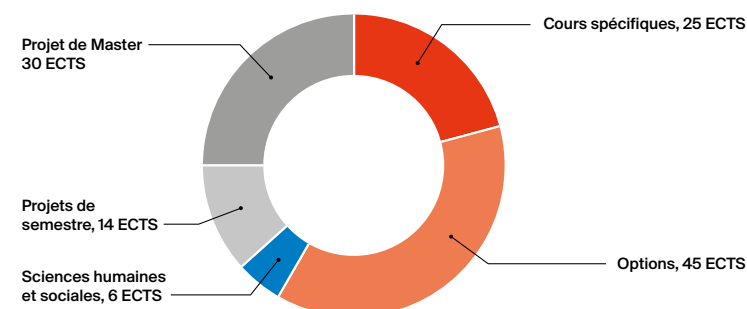
Bachelor 2^e et 3^e années



10 exemples de cours spécifiques/à option :

- Aménagement et gestion du territoire
- Analyse des polluants dans l'environnement
- Analyse du cycle de vie, écobilan
- Ecotoxicologie
- Génie sanitaire, gestion des eaux et des déchets
- Hydrology for engineer
- Législation environnementale et droit de la construction
- Localisation par satellites
- Ouvrages et aménagements hydrauliques
- Physics and chemistry of the atmosphere

Master (120 crédits ECTS)



40 cours à option répartis dans les 3 spécialisations suivantes :

- Chimie et bioprocédés environnementaux
- Ingénierie des eaux, du sol et des écosystèmes
- Monitoring et modélisation de l'environnement

Le Master comprend un stage obligatoire en entreprise.

Mineurs possibles (30 ECTS) dans le cadre des options :

- Design Architecture & Durabilité
- Développement territorial et urbanisme
- Énergie
- Science, Technology and Area Studies - Russie

PERSPECTIVES PROFESSIONNELLES

Votre expertise, vos compétences scientifiques nouvellement acquises et votre polyvalence vous permettront d'accéder à des activités professionnelles très variées dans le domaine public ou privé, dans le secteur industriel ou tertiaire, en Suisse ou à l'étranger.

Vos employeurs potentiels sont en premier lieu les bureaux d'études, bureaux d'ingénieurs-conseils ou en environnement. Vous avez aussi la possibilité d'œuvrer dans les administrations publiques (assainissement, énergie, mobilité, aménagement du territoire, etc.), dans les petites ou grandes entreprises ou dans des institutions de protection de l'environnement (coopération technique...). Finalement, vous pourrez aussi assouvir votre curiosité scientifique par une thèse de doctorat.

Pour plus d'informations: bachelor.epfl.ch

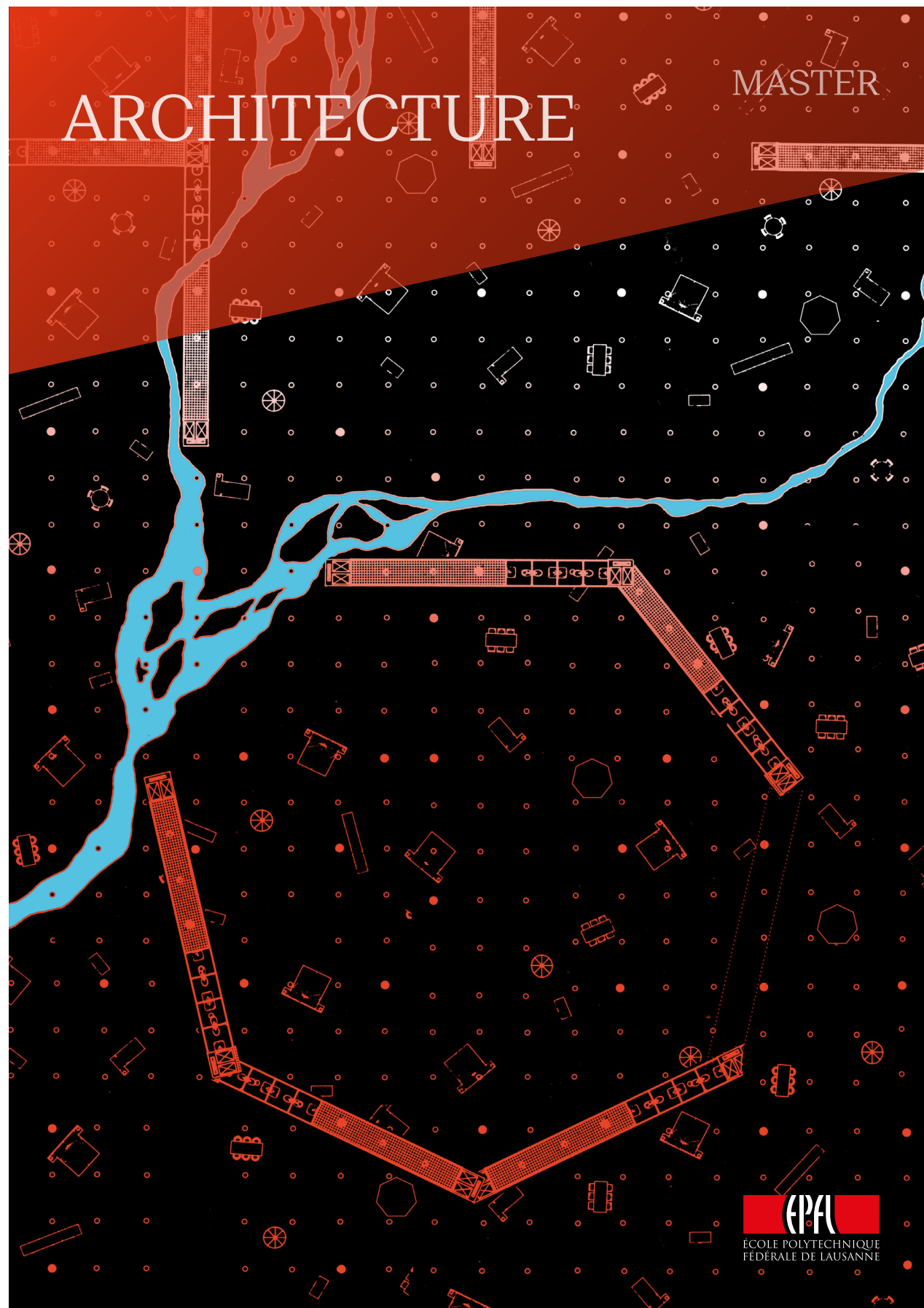
Faculté de l'environnement naturel, architectural et construit (ENAC)

Section des sciences et ingénierie de l'environnement

@mail secrétariat: secreariat.ssie@epfl.ch

Téléphone: +41 21 693 80 71

Web: enac.epfl.ch/ingenierie-de-l-environnement



Combining theory, practice and personal research

At Master's level, students follow an integrated teaching program encompassing current issues, architectural theory, discussions ranging across the full spectrum of design and construction – from design details through to urban planning, and guidance as they embark on their personal research. The course is structured around the production of a dissertation (where the focus is theoretical) and a Master's project, developed with a supervision panel selected by the student.

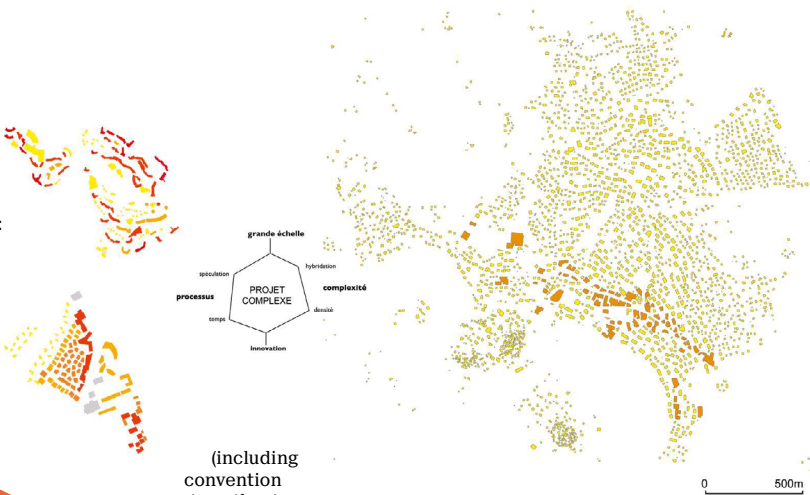


Urbanising the Alps - Fiona Pia

Switzerland's urban area is currently undergoing a process of transformation: the distinction between leisure resort in the mountains as merely a seasonal appendage for skiing purposes and the "real" city has become obsolete – as evidenced by the fact that many urban functions are relocating to the mountains



Nicolas Pierret:
« Pour moi, l'architecture représente un très bon compromis entre des études scientifiques, comme présentes sur le reste du campus, et quelque chose de peut-être plus artistique, plus esthétique. »



(including convention centers, theatres, museums, educational complexes, urban retail businesses and permanent residences). The multiplication and intensity of communication and transport modes are driving these new trends; the mobility network is forging the urban environments of city and mountain into a single entity. This research aims to construct new development strategies based on sustainable architectural and urbanist design paradigms, offering an innovative response to the complex project of combining functionalities and modal interfaces while renewing our understanding of the nature of altitude. This research is undertaken within the ComplexDesign doctoral programme.

This programme is unique in Switzerland, examining the ways in which realising complex projects questions and engages knowledge and practical expertise specific to three areas – law (UNIFR – University of Fribourg), socio-economics (UNINE – University of Neuchâtel) and architecture (EPFL).

<http://complexdesign.epfl.ch>



Urban Recharge Area Steffan Heath and Edouard Philippe

Adrien Alberti:
"I have used algorithms inspired by nature and integrated them into a program that generates architecture."



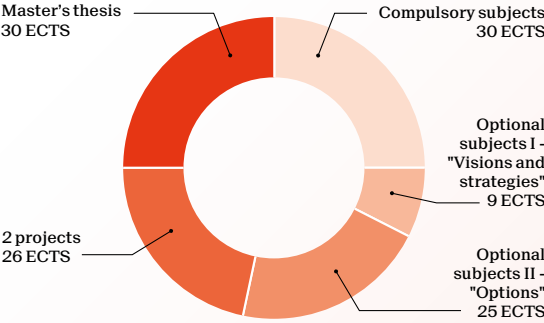
Mexico City and its millions of inhabitants are facing a massive overexploitation of the local water resources. The underground aquifer that is the city's main source of supply is in a critical state of depletion with little hope of recharge. To offset this shortfall the city needs to make better use of the available local resources such as wastewater and rainwater by creating new wastewater treatment plants (WWTPs). Yet when designing an infrastructure of this kind within a dense urban fabric it is essential to give it a clear positive status so that its presence in the city is perceived as an opportunity rather than arousing negative feelings and rejection. This project proposes to combine the WWTP with a municipal swimming pool – to demonstrate what the treatment process can achieve. Located to the west of the city, the project is set in an area where the ground below

the urban fabric is conducive to recharging the aquifer. Located downstream from a retention dam, the planned WWTP generates a green corridor in which the treated water is used to revitalise the river as it flows towards a park located 1.5 km further downstream. The swimming pool is the first element in this green corridor sequence.



Master of Science in ARCHITECTURE

2-year program - 120 ECTS



Students must choose among one of the following orientations:

- B Logement collectif
- D Sauvegarde et patrimoine
- M Projet urbain
- N Construction, matériaux et ressources
- O Forme et type(s)
- P Art et architecture

An orientation is composed of mandatory courses and projects depending on its subject.

Possibility to choose a 30 ECTS Minor in:

- Développement territorial et urbanisme (DTU)
- Design Intégré, Architecture et Durabilité (IDEAS)

Prerequisites for admission:

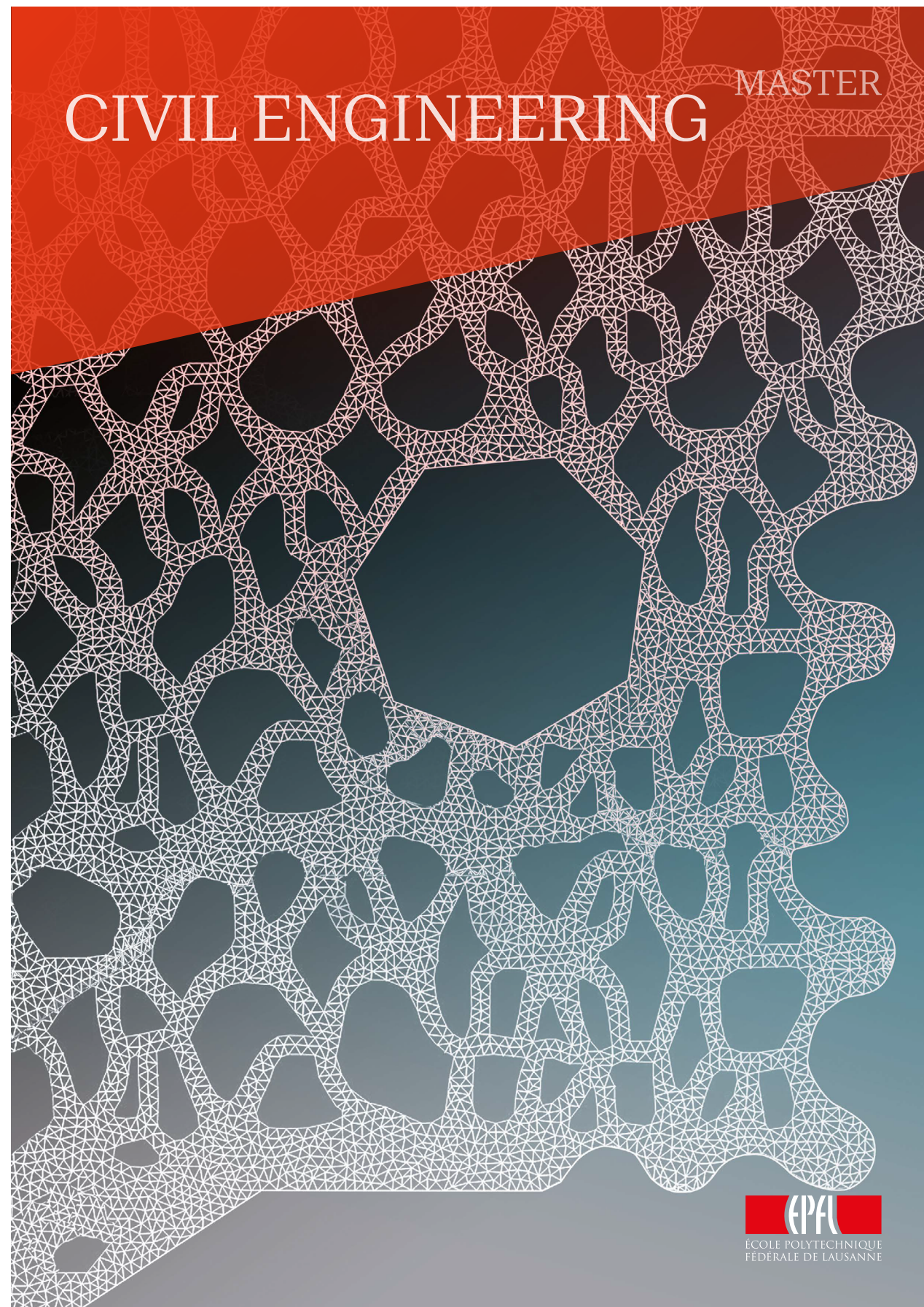
- Bachelor in Architecture
- Practical experience of 12 months
- Excellent knowledge of French (C1)
- Present a portfolio (A4 size) including several projects made by the candidate in the course of his/her studies and possibly practice

Career prospects

Studying architecture is the natural pathway towards a career as an architect, and it can also open up opportunities in many related professions – and in other, more unexpected areas, too: Architect – freelance or in a practice; Government official in a department dealing with the built environment (heritage conservation, regional/landscape planning, urban planning, etc.); Set designer (for shows and exhibitions); Project manager; Logistics specialist; Involvement in a humanitarian project; Real-estate manager; Real-estate expert; Researcher; Teacher; University lecturer; and Publisher.

School of Architecture, Civil and Environmental Engineering
master.epfl.ch/architecture
Contact: secretariat.sar@epfl.ch

	Orientation						Credits
	B	D	M	N	O	P	
Compulsory subjects							
De la structure à l'ornement							3
Superstudio							13
Enoncé théorique de master							8
SHS: introduction au projet							3
Projet SHS							3
Optional subjects I - "Visions and strategies"							
Architecture autonome							3
Difficult Double: Trouble with Classicists					O		3
Why care? Une introduction à l'art contemporain						P	3
La nouvelle architecture internationale suisse							3
Magma et principes							3
Political Economy of Design							3
Projets métaphoriques: d'Archizoom à Koolhaas		D			O		3
Théorie de l'architecture VII			M				3
A Political History of Urban Form			M				3
Optional subjects II - "Options"							
Teaching and research units							
UE A: Site-specific consolidations on architecture						P	4
UE B: Critique architecturale	B						4
UE D: Territoire et société	B						4
UE F: Architecture et réhabilitation	B	D					4
UE H: Graphie							4
UE I: Analogue-Digital-Virtuel							4
UE J: Territoire et paysage			M				4
UE K: Architecture et durabilité: études de performances	B		M	N			4
UE L: Art and architecture: constructing the view I			M		O		4
UE N: Art and architecture: constructing the view II			M		O		4
UE O: Béton. Matière de construction				N			4
UE P: Béton. Construction et préfabrication				N			4
UE R: Introduction au BIM (Building Information Modeling)							4
UE U: Cartography			M		O		4
UE X: Experience design					O		4
UE Y: Description: Operations			M				4
Optional courses							
Apparent realities - Constructing the view							3
Architecture et construction de la ville I	B		M		O		3
Architecture et construction de la ville II	B		M		O		3
Architecture et énergie solaire	B	D		N			3
Art et histoire des jardins							3
Behind/Beyond future cities							3
Building design in the circular economy							3
Caractères architecturaux et urbanismes de l'Islam					O		3
Comfort and architecture: sustainable strategies	B	D		N			3
Critique du projet urbain contemporain			M		O		3
Droit de l'architecte, approfondissements: la réalisation d'une construction							3
Economie spatiale et régional			M				3
Foncier, immobilier, logement	B						3
Habitat et développement urbain			M				3
Histoire de l'habitation	B						3
Histoire du béton				N			3
Interactive conceptual design of structural forms				N			3
Introduction au BIM (Building Information Modeling)				N			3
Le projet du confort dans l'architecture du XXe s.		D					3
Modélisation et représentation informatique I							3
Modélisation et représentation informatique II							3
Projet ENAC		D		N			4
Sociologie urbaine	B		M				3
Structure et architecture							3
Structures complexes				N			3
Summer workshop							4
Technological Innovation		D		N			3
Théories et techniques du projet de sauvegarde	B	D					3
Urbanisme en Asie					O		3
Urbanisme et territoires			M		O		3
Ville africaine: introduction à la planification							3
Ville et mobilité			M				3
Visionnaires éclectiques. Architectures, 2000-2018							3
Visions et Utopies					O		3



Master students learn how to design, construct and maintain the diverse and complex infrastructures which shape our world: buildings, civil engineering structures, roads, railway networks, systems for the exploitation and transportation of water, materials, or energy.

Our master's degree in civil engineering allows students to perfect their fundamental knowledge, while specialising in one of the four proposed programmes:

structural engineering, hydraulics and energy, geotechnics, and transport and mobility.

It makes them capable of expressing themselves through projects that are innovative and safe, which must be achieved within increasingly demanding financial and environmental sustainable conditions.

Designing a floating marina for Lake Geneva

Seeking an innovative way to address the lack of docking sites for leisure boats on Lake Geneva, Jamani Caillet drew the blueprint for a floating marina that offers up to one hundred additional mooring sites. Its location and its unusual construction and use set unique demands on its structure and design.

An analysis of the hydrodynamic conditions of Lake Geneva confirmed the feasibility of the marina's structure. The above-water component, built on hollow re-enforced concrete casings that are connected with pre-stressing cables, is designed to accommodate the moorings, walkways for users, and the temporary storage of materials. The underwater component stabilizes the structure and, most importantly, protects the marina's inside from waves, keeping the boats out of harm's way. A metal framework lined with tree trunks acts as a breakwater, keeping waves to a minimum.

The floating marina can be accessed by shuttle boats. The innovative structure challenges previous approaches, while its implementation and construction must be conceived with the protection of the lakefront in mind.

Watch the video:



Olivia Künzli:

"If you are looking for a dynamic and international atmosphere, you should come to EPFL. And more specifically about civil engineering: I feel that the program is special because technical skills are here very closely related to creativity."

Watch the video:



Jamani Caillet's project for a Lake marina



Historical study on the Jument lighthouse and proposals for intervention

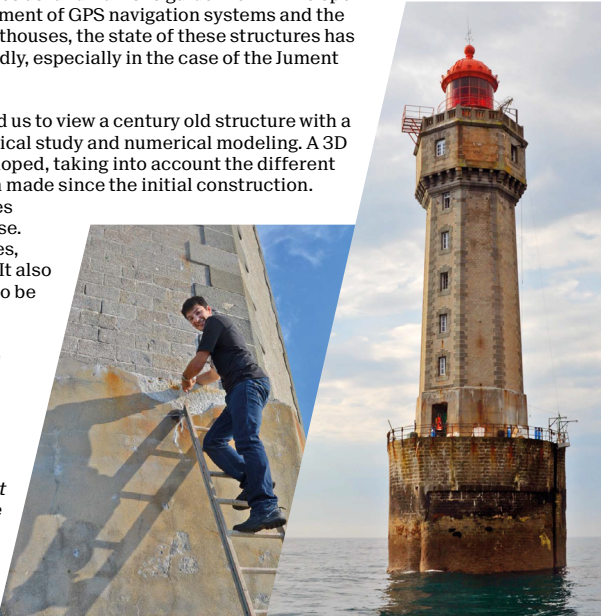
The Iroise Sea, at the most western point of Brittany, is known for its violent storms and deadly shipwrecks. Since 1853, when the mapping of the French coasts began, marine navigation in the area has become much safer. However, for close to a century, navigators only had the lights from the lighthouses as landmarks to guide them in the open sea. With the development of GPS navigation systems and the automation of lighthouses, the state of these structures has deteriorated rapidly, especially in the case of the Jument lighthouse.

This project has permitted us to view a century old structure with a new regard, combining a historical study and numerical modeling. A 3D finite element model has been developed, taking into account the different structural reinforcements that have been made since the initial construction.

The model has been submitted to impact forces resulting from breaking waves striking the lighthouse. The dynamic non-linear analysis was completed in phases, allowing the history of damage to the masonry to be retraced. It also enabled a scheme of the current state of cracking in the structure to be obtained.

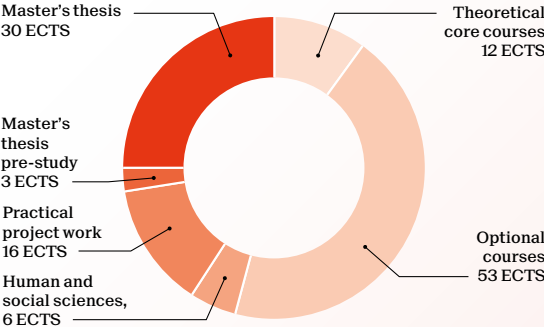
It is a challenge to find economic solutions for structures that will be submitted to such climatic conditions. The Ultra-High Performance Fibre Reinforced Concrete (UHPFRC), due to its outstanding mechanical and corrosion resistance, will certainly become the reference material for reinforcing such maritime structures in the future.

Christophe Loraux's master project at the Jument lighthouse



Master of Science in CIVIL ENGINEERING

2-year program - 120 ECTS



The program includes an 8-week compulsory internship

Students may choose to pursue a 30 ECTS specialization:

- B Geotechnical Engineering
- C Transportation and Mobility
- D Structural Engineering
- E Hydraulic Engineering and Energy

Or a 30 ECTS Minor:

- Computational Science and Engineering
- Design Intégré, Architecture et Durabilité (IDEAS)
- Energy
- Management, Technology and Entrepreneurship
- Urban Planning and Territorial Development

A specialization or Minor is included in the 120 ECTS credits.

The EPFL civil engineering academic performances are top-rated at the international level. Its master curriculum is widely recognized for the high quality of its training and offers very good perspectives of professional insertion. The increased demand in Switzerland for highly qualified engineers in the civil engineering sector provides excellent career prospects for our students. Civil engineering consulting firms, state administrations and construction companies all benefit from hiring our graduates. Furthermore, the scientific skills and the versatility of our engineers also allow them to pursue very diverse professional activities. Whatever path you choose, you will collaborate with numerous partners from the domains of architecture, environment, sociology, economy, energy, or politics. The know-how of the Swiss civil engineers is very well respected abroad, which also opens the door to an international career.

School of Architecture, Civil and Environmental Engineering
master.epfl.ch/civilengineering
Contact: sgc@epfl.ch

	Specialization			Credits
Theoretical core courses (4 courses to be chosen)				12
Building energetics				3
Dynamique des structures		D		3
Fundamentals of traffic operations and control			C	3
Geomechanics	B			3
Ouvrages hydrauliques et aménagements hydroélectriques			E	3

Optional courses				53
Advanced Composites in Engineering Structures			D	3
Advanced continuum mechanics			D	2
Advanced design of concrete structures			D	3
Advanced methods in computational solid mechanics	B		D	3
Advanced Steel Design			D	3
Analyse et gestion des risques	B		D	E 3
Analyse et management des risques industriels				3
Barrages et ouvrages hydrauliques annexes	B		D	E 3
Conception des constructions en bois			D	3
Data and artificial intelligence for transportation		C		4
Decision-aid methodologies in transportation		C		4
Développements en économie des transports		C		3
Droit de la construction pour ingénieurs I	B		D	E 2
Droit de la construction pour ingénieurs II	B		D	E 3
Éco-morphologie fluviale				E 3
Economie des réseaux d'infrastructures		C		3
Économie hydraulique				E 2
Energy Geotechnics	B			E 3
Engineering geology for geo-energy	B			3
Esthétique des ouvrages de génie civil			D	2
Études d'impact	B			E 3
Exploitation ferroviaire		C		3
Géologie de la construction et de l'environnement	B			E 3
Geophysics for engineers	B			3
Gestion de la maintenance des infrastructures	B	C		3
Hydraulique fluviale et aménagement des cours d'eau	B			E 3
Management de projet et analyse du risque		C		4
Matériaux et structures			D	3
Modélisation des systèmes énergétiques		C		E 3
Nonlinear analysis of structures			D	3
Ondes de crue et de rupture de barrage				E 3
Planification intégrée des infrastructures d'énergie				E 3
Ponts en béton			D	3
Programming Concept in Scientific Computing	B			4
Reservoir geo-mechanics engineering	B			3
Seismic engineering	B		D	E 3
Selected topics in mechanics of solids and structures	B		D	3
Slope stability	B			3
Structure et architecture			D	3
Structures complexes			D	3
Structures en béton, chapitres choisis			D	3
Structures en métal, chapitres choisis			D	3
Structures existantes, bases	B		D	E 3
Structures existantes, chapitres choisis	B		D	E 3
Systèmes de transports		C		3
Thermodynamics of comfort in buildings				E 3
Travaux souterrains	B			E 3
Urban hydraulic systems				E 3
Villes et transports	B	C		3
Voies de circulation		C		3

Human and social sciences					6
Project in human and social sciences					6

Practical project work					16
Laboratoire GC					4
Projet ENAC ou UE architecture					4
Projet de construction					4
Projet de systèmes civils					4
Summer Workshop					4
UE génie civil: Construction durable					4

Master's thesis pre-study					3
Pré-étude projet de master					3

ENVIRONMENTAL SCIENCES AND ENGINEERING

MASTER



In the environmental field, our planet is facing major challenges: climate change, scarcity of resources such as drinking water, pollution, human population growth or loss of biodiversity. Environmental issues are not only diverse, but also increasingly complex. Although inventing appropriate solutions to these issues involves human, economic and social dimensions, taking into account scientific and technical progress is paramount.

Environmental engineers are trained to solve problems at the crossroad between science and society arising from the complex interaction of human beings with their natural environment. Curious by nature, I focused my master in Water, Soil and Ecosystem Engineering which offers core courses on water-related topics coupled with strong technical know-how in Geographic Information Systems (GIS) and their use for spatial analysis and visualization. Led by my interest in societal issues, I chose my Master's Project on the understanding and modeling of transmission of waterborne epidemic diseases (cholera in Bangladesh) realized at the University of Michigan in Ann Arbor, USA. In this project, I applied concepts in hydrology, optimization and modeling together with programming and spatial analysis to produce and explore data, analyze it and communicate my findings. The possible tasks that I would be able to perform include flood risk evaluation, water management and spatial data analysis and representation which all involve modeling and programming. Possible employers are consulting-engineering companies working in the field of water management and flood mitigation, large firms needing specialists in spatial data analysis and of course Swiss or international institutions like the WHO working in diseases prevention.

Javier PEREZ - SAEZ

Magali Bassan:
"I really liked the opportunity given by this Master to do internships and work on concret projects. I had the opportunity to work in Senegal and Togo to develop water supply and sanitation. I also worked on organic waste valorization with biogas in Valais. Since the beginning of my career, I've always been able to combine my interest for water sanitation and helping developing countries."

Patrick Astori:
"The Master's degree in environmental engineering teaches you how to solve concret problems, directly related to real situations/ settings. During my studies, I worked on the water barriers in Venise, on the development of photovoltaics in Valais or on the third correction of the Rhône. All these examples clearly show the broad fields covered by environmental engineers, as well as their utility."

I hope this glimpse of activities has convinced you of the opportunities offered by the Environmental Engineering curriculum.

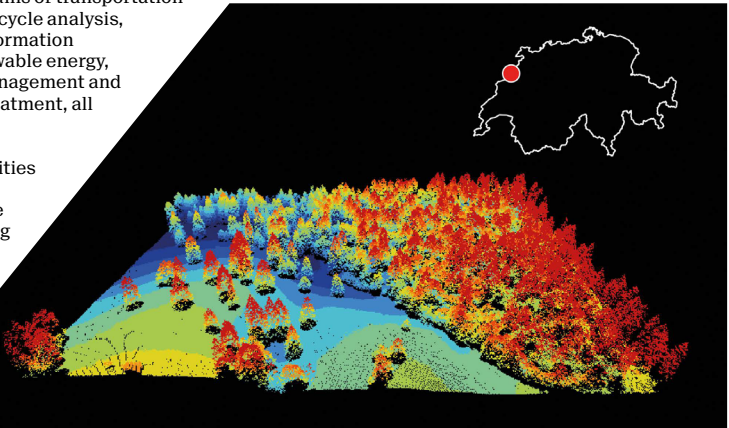
Matthew PARKAN

Have you ever wanted to understand why avalanches are so difficult to predict? How observing ants can help in network routing? How PET bottles can be used to disinfect water? Then the Master SIE is made for you!

During my Master in Environmental Modeling and Monitoring, I was able to exercise a diverse set of skills; from planning irrigation networks for arid regions to predicting atmospheric temperatures in Greenland using artificial intelligence. Pretty quickly, geospatial analysis became of special interest to me and I discovered how multidisciplinary it is. Indeed, most environmental studies involve maps and spatial decisions. Questions such as 'Where is the best place to install this wind turbine?' or 'How does the topography of this water catchment influence the risk of flooding?' are a common sight in the problem landscape.

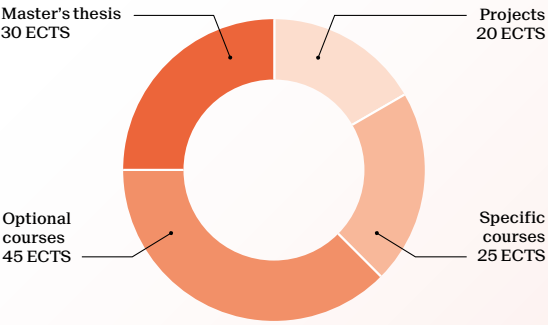
Before my PhD studies, I worked at the Vaud Forest Service to create forest canopy maps and worked in a natural reserve -the Grande Cariçaie- to analyze erosion dynamics.

Overall, as an environmental engineer, you will be able to implement both down to earth and high tech solutions. Most of the young environmental engineers work in the domains of transportation systems, life cycle analysis, geographic information consulting, renewable energy, natural reserve management and water/wastewater treatment, all around the world.



Master of Science in ENVIRONMENTAL SCIENCES AND ENGINEERING

2-year program - 120 ECTS



The program includes an 8-week to 6-month compulsory internship

Students are requested to deepen their training either with a 30 ECTS Specialization in:
A Chemical and Environmental Bioprocess
B Water, Soil and Ecosystems Engineering
C Monitoring and Modeling of the Environment

Students can also opt for a 30 ECTS Minor.
Minors recommended with this Master:
• Energy
• Integrated Design, Architecture and Sustainability
• Science, Technology and Area Studies - Russia
• Urban Planning and Territorial Development

Other Minors are possible.
A specialization or minor is included in the 45 optional credits.

Career Opportunities

Your expertise, your newly acquired scientific skills and versatility will allow you to access a wide variety of professional activities in the public or private sector, in industry or the service sector, in Switzerland or abroad. Your prospective employers are primarily design offices, engineering consultants or environmental engineering firms. You also have the opportunity to work in public administration (sanitation, energy, mobility, spatial planning, etc.), in small or large companies or in environmental protection institutions (technical cooperation...). Finally, you may also decide to satisfy your scientific curiosity by embarking on a doctoral thesis.

School of Architecture, Civil and Environmental Engineering
master.epfl.ch/environment
Contact: secretariat.ssie@epfl.ch

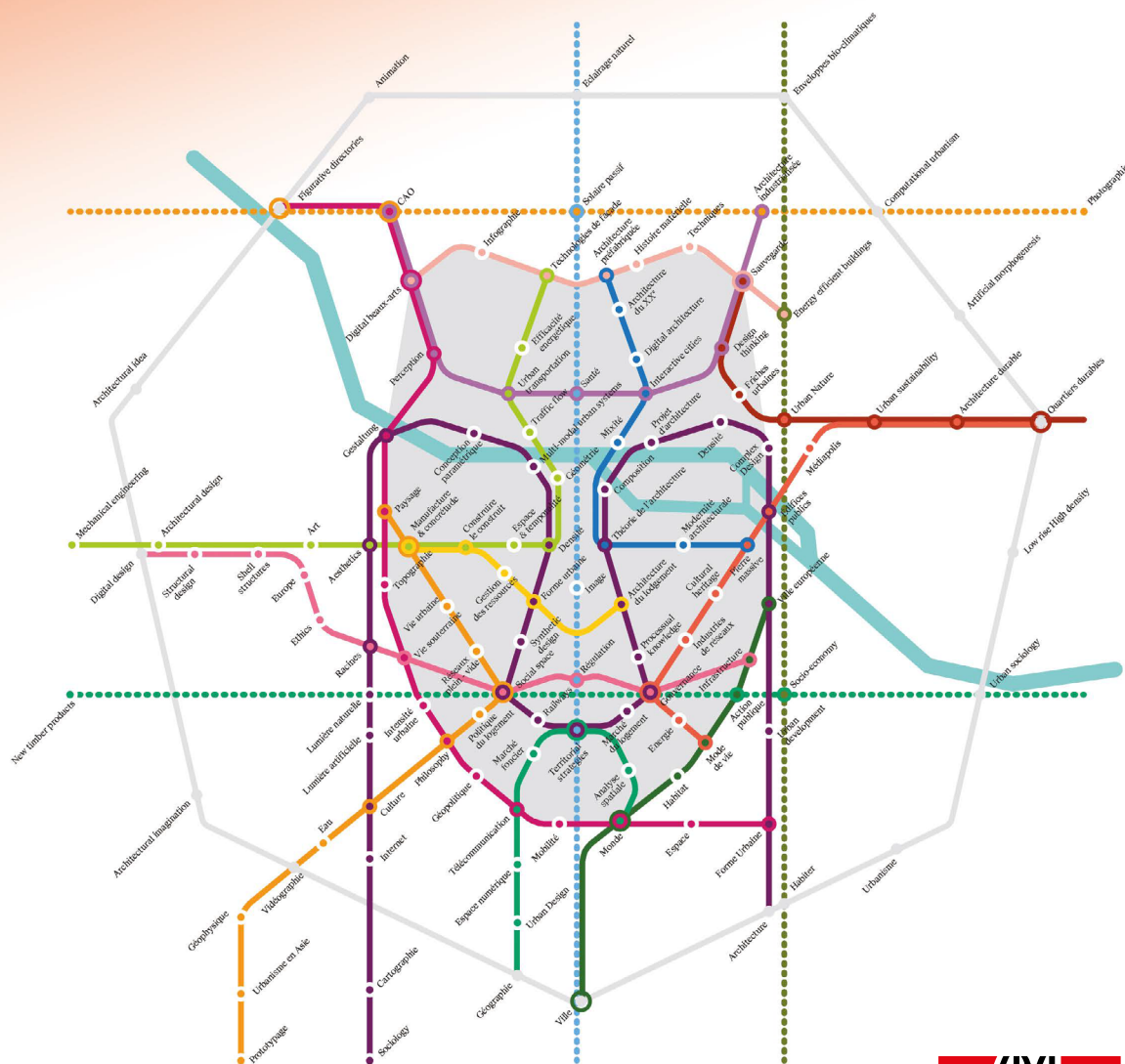
	Specialization			Credits
Projects				20
Design project				10
SIE/ENAC Project or Summer workshop				4
Project in human and social sciences				6

Specific courses				25
Air pollution and climate change	A			5
Environmental Transport phenomena		B		5
Geomonitoring			C	5
Spatial statistics and analysis			C	5
Water and wastewater treatment	A			5
Water resources engineering		B		5

Optional courses				45
Advanced Satellite Positioning			C	4
Analyse et management des risques industriels	A			3
Applied wastewater engineering	A			3
Biomining: from nature to application	A			4
Bio-ingénierie des cours d'eau et milieux naturels		B		2
Concepts in Ecological Engineering		B		4
Design de SIG			C	4
Development Engineering	A			4
Distributed information systems			C	4
Distributed intelligent systems			C	5
Droit: contrats et responsabilité professionnelle	A	B	C	3
Economie hydraulique		B		2
Eco-morphologie fluviale		B		3
Energy conversion and renewable energy	A			3
Environnements de travail, risques professionnels	A			3
Experimental design and data analysis with R			C	2
Exploratory data analysis and geovisualization		B	C	4
Etudes d'impact	A	B		3
Fate and behaviour of environmental contaminants	A			4
Fluvial biogeosciences		B		4
Génie des bioprocédés environnementaux	A			5
Gestion foncière et droit foncier			C	3
Groundwater and soil remediation	A			4
Hydraulique fluviale et aménagement de cours d'eau		B		3
Hydrogeophysics		B		3
Hydrologie urbaine		B		4
Image Processing I			C	3
Image processing for Earth observation			C	3
Introduction to database system			C	4
Limnology		B		5
Material and energy flow analysis	A			4
Physics and hydrology of snow		B		4
Recycling of materials	A			2
Risques hydrologiques et aménagements		B		3
Sanitary engineering in developing countries	A			2
Sensor Orientation			C	4
Spatial Decision Support Systems			C	3
Solid waste engineering	A			4
Statistiques multivariées avec R		B	C	4
Sustainability Assessment of urban systems			C	3
Systèmes de management environnementaux	A			2
TP de bioprocédés environnementaux	A			5
Water quality modeling	A	B		4

ARCHITECTURE AND SCIENCES OF THE CITY

DOCTORAL SCHOOL



The Doctoral Program in Architecture and Sciences of the City (EDAR) invites doctoral students to accomplish an interdisciplinary exploration of inhabited space in the international and dynamic environment of the EPFL.

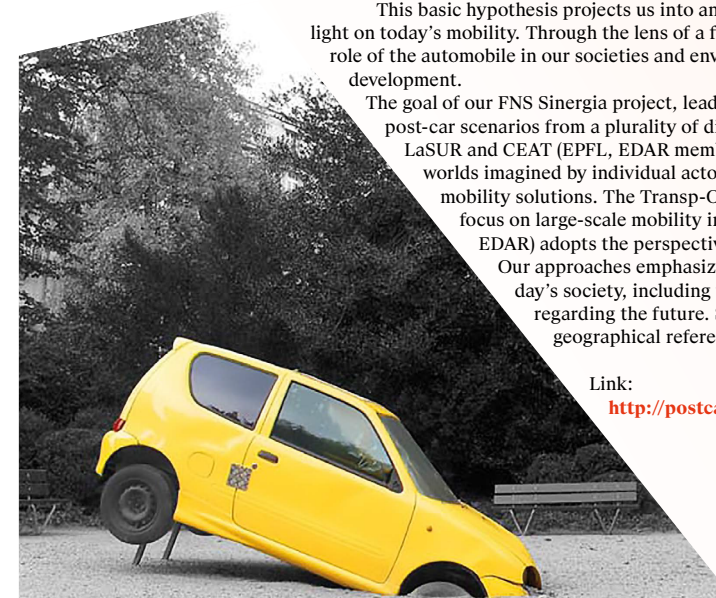
The program brings together the world of architecture (history, theory, projects) and that of urban sciences (geography, urban sociology, environmental economics, housing and networking, urbanism and spatial planning). While the EDAR program stays open to mathematics, the sciences of matter and life and the science of engineering it maintains particularly close relations with the School of Architecture, Civil and Environmental Engineering (ENAC).

“What if there were no cars?”

This basic hypothesis projects us into an alternative world capable of shedding a new light on today's mobility. Through the lens of a formalized PostCarWorld, we shall appraise the role of the automobile in our societies and envision new possibilities for mobility and spatial development.

The goal of our FNS Sinergia project, lead by the Chôros lab, is to simulate diverse post-car scenarios from a plurality of disciplinary points of view. The Chôros, LaSUR and CEAT (EPFL, EDAR members) with the IRE (USI) examine post-car worlds imagined by individual actors, and the social potentials of emerging mobility solutions. The Transp-OR lab (EPFL), and the IVT (EPFZ) focus on large-scale mobility infrastructures. The Lab-U (EPFL, EDAR) adopts the perspective of urban and landscape design. Our approaches emphasize the observation of present-day's society, including the diversity of its expectations regarding the future. Swiss spaces are our main geographical reference.

Link:
<http://postcarworld.epfl.ch>



Loïc Fumeaux graduated as an architect in 2007 at EPFL. His Master's thesis was about sustainability integration from urban scale to the architectural details. Two years later he became a studio assistant at the LAST (Laboratory of architecture and sustainable technologies) headed by Prof. Emmanuel Rey. After a period dedicated to teaching, he began a PhD focused on the integration of sustainability criteria into the design process of temporary event infrastructures. A field of architecture booming but still little explored, for which the characteristics of use flexibility and economic efficiency often take precedence over considerations related to their impacts.

From a methodological view, his research is based on a diagnose of existing infrastrucures which are assessed using a multicriteria approach that take into account multiples parameters of sustainability. From this assessment, the research imagines a preliminary conceptual design which propose strategies to reach a high level of comfort, an optimal use of resources, a minimization of impacts, and integration of bioclimatic strategies to achieve it. From there, through a process of integrated design involving interdisciplinary actors (users/engineers/builders/operator), the concept will be optimised to achieve an operational prototype which meet the initial objectives.



As a PhD student at the Urban and Regional Planning Community (CEAT), my research focuses on the effects of institutional fragmentation on the development of urban centers, and in particular investigates municipalities' ability to interact in order to collectively respond to regional challenges. To do this, I analyze changes in the relationships between actors and the inter-communal relations resulting directly from the realization of urbanization projects that sit astride institutional frontiers.

The scope of empirical lessons learned from case studies is not limited to Switzerland - my personal field of investigation - but aims more generally at increasing knowledge about the complex system of relationships among metropolitan communities in an institutional setting that historically attributes considerable autonomy to local government. The scope of my research subject also stems from a longstanding personal questioning of the possibility of aligning two imperatives: the conservation of the intrinsic values of local democracy and the development of true political cybernetics in fragmented metropolitan areas. In my lab and in the doctoral program in general, I find a very diverse range of academic skills and scientific questions that allow me to build my research by successive increments.

As a young researcher, I find that this great diversity and the richness of exchanges are among the most stimulating aspects of this environment.

Loïc Fumeaux



Marc Antoine Messer

Fiona Pia

Alpine ComplexDesign

Supported by the Swiss National Science Foundation, the ComplexDesign doctoral program studies through interdisciplinary means complex projects, including major strategies involving infrastructure, equipment and habitat over an area of at least 100'000m2.

Case studies were selected including the city, the countryside and the mountains.

Fiona Pia is currently researching Urbanization of the Alps, in order to analyze complex alpine projects in contemporary context.

The concept of urban sprawl is highlighted in the Swiss news more than ever and especially apparent in the Alps. Massive urbanization in the mountains initiated by the development of ski resorts, specifically in sites over 1400 meters, is continuing to take momentum in an uncontrolled way.

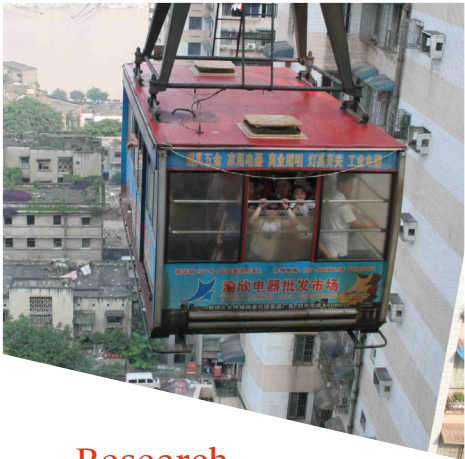
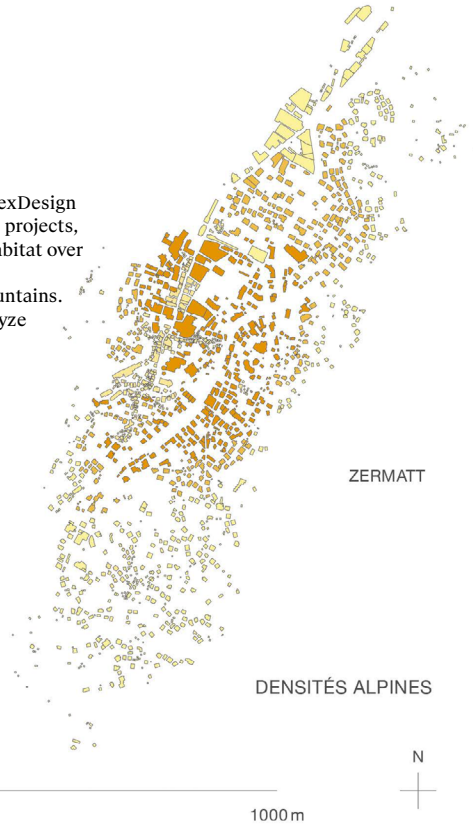
Alpine urban sprawl is the result of the multiplication of individual chalet style houses, causing great controversy. The people's acceptance of the Franz Weber initiative in March 2012 marks an exemplary shift.

The urbanization of the Alps requires new urban, legal and economic solutions. How should the Alps be urbanized or deurbanized today? Is the Alpine Complex Project a more relevant solution than developing using current piecemeal construction in the urbanization model of the Alps?

Links:

<http://complexdesign.epfl.ch>

<http://people.epfl.ch/fiona.pia>



Research opportunities:

Active within almost 30 labs, mainly from the School of Architecture, Civil and Environmental Engineering, the EDAR program receives three times a year new doctoral students interested in its scientific orientations which encompass four research areas :

- Sciences of the City
- History, Theory, Heritage
- ComplexDesign
- Integrated Design, Architecture, Sustainability

Application deadlines

The on-line application to the doctoral program in Architecture and Sciences of the city (EDAR) can be received by January 15, April 30 and September 15.

For any information, please visit our website.

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Director: Prof. Vincent Kaufmann

Deputy-head: Prof. Luca Ortelli

Program administrator: Sandra Bottà

EDAR - Affiliated laboratories

Architecture, Criticism, History and Theory

ACHT - PATT Christophe van Gerrewey

Design Studio of the Conception of Space

ALICE - Prof. Dieter Dietz

Centre for Area and Cultural Studies

CDH - MER Florence Graezer Bideau

Urban and Regional Planning Community

CEAT - MER Jérôme Chenal

Digital Humanities Laboratory

DHLAB - PATT Frédéric Kaplan

Laboratory on Human-Environment Relations in Urban Systems

HERUS - Prof. Claudia R. Binder

Laboratory for Timber Constructions

IBOIS - Prof. Yves Weinand

EPFL Laboratory Basel

LABA - Prof. Harry Guggler

Laboratory of Architecture and Urban Mobility

LAMU - Prof. Inès Devanthery-Lamunière

Arts of Sciences Laboratory

LAPIS - Prof. Nicola Braghieri

Laboratory of Architecture and Sustainable Technologies

LAST - Prof. Emmanuel Rey

Urban Sociology Laboratory

LaSUR - Prof. Vincent Kaufmann

Construction and Conservation Laboratory

LCC 2 - Prof. Luca Ortelli

Media and Design Laboratory

LDM2 - Prof. Jeffrey Huang

Interdisciplinary Laboratory of Performance-Integrated Design

LIPID - Prof. Marilynne Andersen

Theory and History of Architecture Laboratories

LTH 2, 3 - Prof. Roberto Gargiani and Prof. Bruno Marchand

Chair Management of Network Industries

MIR - Prof. Matthias Finger

Laboratory of Techniques and Preservation of Modern Architecture

TSAM - Prof. Franz Graf

Economics and Environmental Management Laboratory

LEURE - Prof. Philippe Thalmann

Laboratory of Urbanism

LAB-U - Prof. Paola Viganò

Laboratory for Architecture as Form

FORM - Prof. Kersten Geers

Laboratory of Digital Culture for Architectural Projects

CNPA - Prof. Bernard Cache

Laboratory of Elementary Architecture and Studies of Types

EAST - Prof. Martin Fröhlich

Laboratory of Underground Architecture

SUB - Prof. Dominique Perrault

Structural Exploration Lab

SXL - PATT Corentin Fivet

CIVIL AND ENVIRONMENTAL ENGINEERING

DOCTORAL SCHOOL

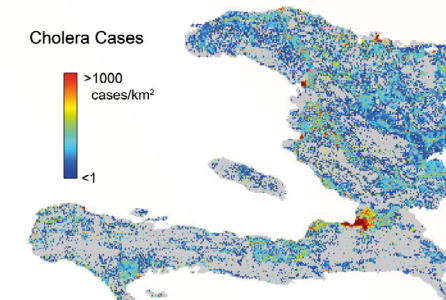


The Doctoral Program in Civil and Environmental Engineering (EDCE) at EPFL is a multi-disciplinary program designed to tackle the most challenging problem of our time: fostering a vibrant and productive society while ensuring environmental sustainability.

This challenge is being addressed by creative interactions between science and engineering. The strength of EDCE is that it spans a remarkably broad research spectrum: from rock mechanics to microbiology, from rivers to roads and from the dams to glaciers. EDCE offers the educational model necessary to become a leader in fast-paced, high-tech industries and academia.

Spatial epidemiology of waterborne disease

The laboratory of Ecohydrology focuses on research at the interface of hydrology, geomorphology and ecology under an integrated framework of analysis with an aim for a general theory. The main effort in the doctoral program is devoted to the development of a new research field across physical and biological sciences: spatial epidemiology of waterborne disease, with significant impacts on science and public health practice. Waterborne diseases are infections that predominantly are transmitted through contact with or consumption of contaminated water. They can strike humans, animals and even plants. Spatially explicit mathematical models of waterborne infections are fast revolutionizing epidemiology as they can provide key insights into the course of an ongoing epidemic, potentially aiding real-time emergency management in allocating resources and anticipating the impact of alternative interventions. We aim at a new generation of spatially explicit multilayer-network models of waterborne epidemics and epizootics. Specifically we study cholera, one of the most important global health hazards, and proliferative kidney disease in salmonids, which has a critical impact on fish-stock with major ecological and bio-economic consequences.



Using lasers to study the internal dynamics of idealized avalanches to understand the mechanisms of material entrainment from below.

Snow and debris avalanches pose a threat to life and have the potential to greatly damage communities in mountainous areas, yet their properties and internal dynamics are highly complex and difficult to investigate. Understanding the processes at play within such flows is key to the prediction of their eventual size and velocity, as well as the areas at risk, and the aim of my research is to study the effects of material entrainment from below on the dynamics of idealized avalanches in the lab. This allows a tight control of the avalanche properties, without the complications and dangers associated with these phenomena.

In the experiments an avalanche of fluid is seeded with tiny fluorescent particles and released by a dam-break. A laser sheet illuminates a stream-wise slice of the flow allowing measurements of the internal velocities to be taken without intrusively disturbing the flow.

The avalanche may travel over an entrainable region, and we can examine how this alters the dynamics. Parameters are varied one by one: with the final goal of linking all of this together in a theory able to describe more complex natural flows. Hopefully this work will play a part in improving the models used for the prediction of such natural hazards.

This project combines lab work and data analysis with fluid dynamical theory and numerical methods, and it is this variety that I enjoy. Coming from a theoretical background, I was excited to start performing experiments, and during my PhD studies so far I have learnt how to apply sophisticated laser and imaging techniques to laboratory avalanches with differing levels of complexity.

With the facilities available at EPFL, I have the opportunity to use cutting-edge procedures, which allows me to present my results at international conferences alongside some of the best researchers in the field - which is an incredibly nerve-wracking, but really valuable, experience!

Belinda Margaret Bates, PhD student

Raluca Tereza Constantin, PhD Student

Designing earthquake resistant buildings

Currently I am a PhD student in my 3rd year in the Earthquake Engineering and Structural Dynamics Laboratory. My research focuses on developing the seismic design guidelines for reinforced concrete core walls. What attracted me very much to this topic and EPFL was the practical nature of the research topic as well as the opportunity to perform large-scale testing. Moreover the project is quite comprehensive involving numerical, analytical as well as experimental tasks. No time to get bored... During the two years already spent at EPFL, I have discovered here a very high level of research and education. Of course, it asks for a lot of work but also brings a lot of satisfaction. People here are very passionate about their work and at the same time supportive and helpful to yours. The university environment is really nice and international. When I first came here I didn't really knew anybody but I remember that my colleagues really made me feel welcome and tried to help me integrate socially. I now also try to do the same thing with all the newcomers to sort of keep the tradition going...

Application Deadlines:

The applications to the doctoral program in Civil and Environmental Engineering (EDCE) can be received by January 15, April 30 and September 15. Your complete application material must be received by the doctoral program at EPFL prior to the deadline at which you wish your application to be considered.

Research opportunities:

More than 40 labs, mainly from the School of Architecture, Civil and Environmental Engineering, but also from the School of Basic Sciences and of Engineering, are offering PhD research opportunities along 4 main streams:

- Structural Engineering
- Systems Engineering
- Environmental Resources Engineering
- Chemical & Biological Processes

Job market:

Some of our PhD graduates have joined the faculty of good universities around the world. To facilitate the access to the academic market, EDCE is encouraging the mobility of its students through "mobility awards" to increase their visibility and, therefore, their competitiveness on this market. Many other PhD graduates have been hired by companies or consultants offices, or have established their own start-up based on the tools and skills developed during their PhD thesis. To foster this line, EDCE encourages participation in research projects with the industry by providing sufficient flexibility to allow the students to accomplish the requirements of the program in this context, while not compromising on the quality of their research.

EDCE doctoral program
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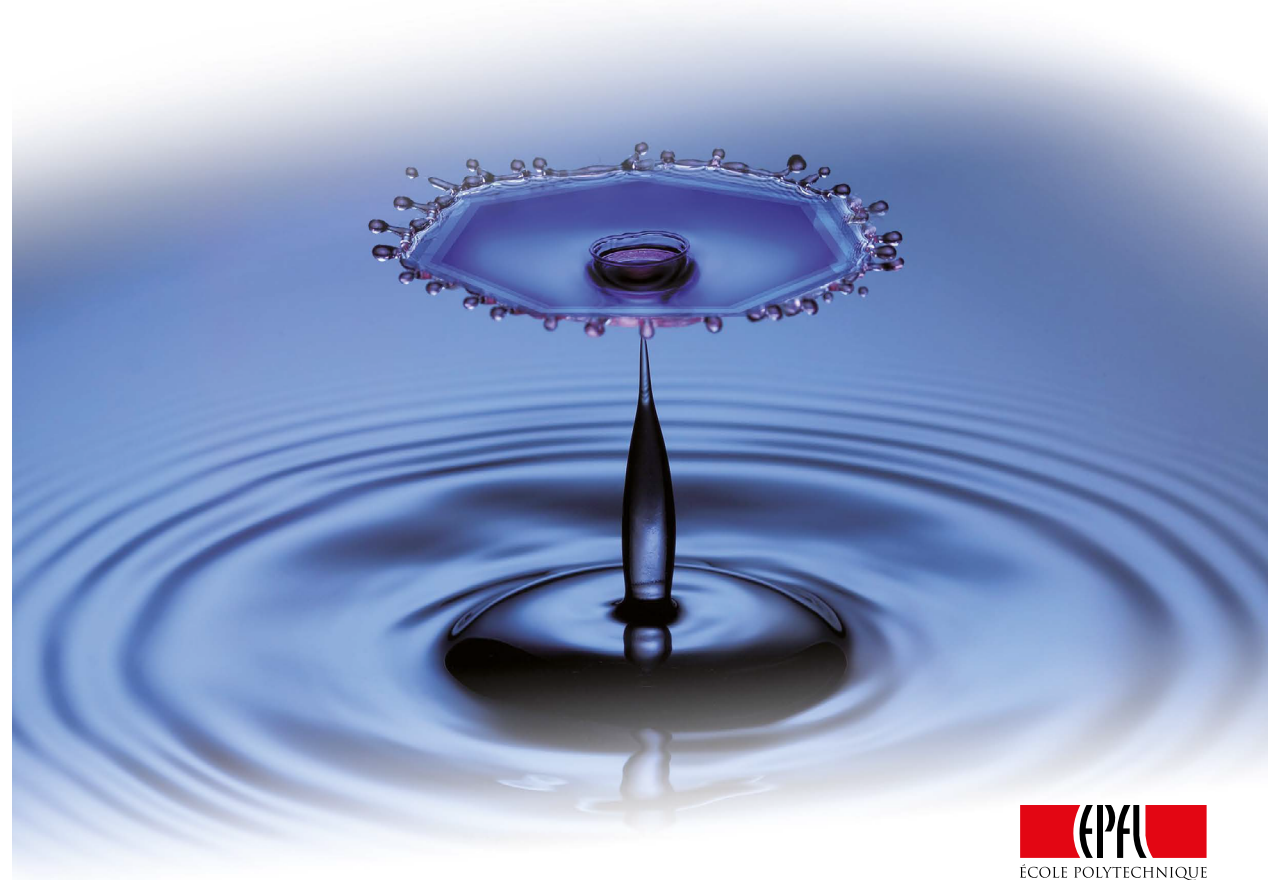
Director: Prof. Tamar Kohn
Administrator: Emma Sorrentino

<http://phd.epfl.ch/edce>

Lab	Structural Eng.	Systems Eng.	Environmental Resources Eng.	Chemical & Biological Processes
Interdisciplinary Laboratory of Performance-Integrated Design	•			
Applied Computing and Mechanics Laboratory	•	•		
Chair of Timber Construction	•			
Composite Construction Laboratory	•			
Computational Solid Mechanics Laboratory	•			
Earthquake Engineering and Structural Dynamics Laboratory	•			
Environmental Hydraulics Laboratory			•	
Hydraulic Constructions Laboratory		•	•	
Soil Mechanics Laboratory - Chair gaz naturel Petrosvibri	•	•	•	
Solar Energy and Building Physics Laboratory			•	
Steel Structures Laboratory	•			
Structural Concrete Laboratory	•			
Structural Maintenance and Safety Laboratory	•			
Construction Materials Laboratory	•			
Earth and Planetary Science Laboratory			•	
Economics and Environmental Management Laboratory			•	
Transportation and Mobility Laboratory		•		
Urban Transport Systems Laboratory		•		
Advanced Oxidation Processes Group			•	
Atmospheric Particle Research Laboratory			•	
Central Environmental Laboratory			•	
Distributed Intelligent Systems and Algorithms Laboratory		•		
Ecological Engineering Laboratory			•	•
Ecological Systems Laboratory			•	
Environmental Chemistry Laboratory			•	
Environmental Microbiology Laboratory			•	
Environmental Remote Sensing Laboratory			•	
Geodetic Engineering Laboratory		•	•	
Geographic Information Systems Laboratory		•		
Solid Waste Engineering		•	•	
Laboratory for Biological Geochemistry			•	
Laboratory for Environmental Biotechnology			•	
Laboratory for Water Quality and Treatment			•	
Laboratory of Cryospheric Sciences			•	
Laboratory of Ecohydrology			•	
Laboratory of Environmental Toxicology			•	
Laboratory for Human-Environment Relations in Urban Systems		•		
Physics of Aquatic Systems Laboratory - Margaretha Kamprad Chair			•	
Prof. Hering Group in Environmental Chemistry			•	
Wind Engineering and Renewable Energy Laboratory			•	
Laboratory of Experimental Rock Mechanics	•			
Geo-energy Laboratory - Gaznat Chair on Geo-energy			•	
Stream Biofilm and Ecosystem Research Laboratory			•	•
Structural Exploration Laboratory	•			
Urban Sociology Laboratory		•		

MECHANICS

DOCTORAL
SCHOOL



As mechanics problems are found across the entire scope of industries and fields of application, research within the EPFL mechanics doctoral program spans the full range of relevant themes, including microfluidics, wind energy, geomechanics, nano- and micro-mechanics, energy harvesting, soft materials, biomechanics, composites, and fracture. Studies include innovative experiments, new theories, and advanced simulation methods, often in combination and including multiscale and micro-macro scale bridging.

Bio-cemented soils: From the laboratory to the market

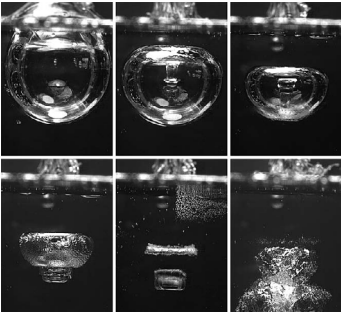
A technology developed at the Laboratory for Soil Mechanics (LMS) of EPFL is scaling up, targeting industrial applications. A research carried out at LMS since 2008 led to the conception of an innovative design and application method of soil bacteria for producing cementitious particles in subterranean applications. The technology aims to provide engineering consulting companies with innovative, cost-efficient and environmental-friendly solutions for stabilizing and strengthening soils in a series of geotechnical problems. A patent application has been filed in 2017 by EDME student Dimitrios Terzis and his supervisor Prof. Lyesse Laloui in collaboration with EPFL's technology transfer office.

During the last ten years two doctoral theses have been carried out at LMS putting the focus on the complex bio-chemo-mechanical phenomena involved in the utilization of bacteria for producing microbe cement in the subsurface. The project has recently received financial support from prestigious innovation grants including the Academia-Industry Training 2016, took place between Bangalore, India and Zurich, as well as the Innovation in Tradition grant provided by the Giovanni Lombardi Foundation and ENAC's InnoSeed program.



Investigations on collapsing cavitation bubbles

Cavitation, i.e. the formation of vapor cavities in depressurized liquid zones, is a major source of erosion and vibration damage in many industrial systems such as hydraulic machines. The damage is associated to the shooting of high-speed liquid jets, to the emission of shock waves and to



the extremely high temperatures reached at the last stage of the collapse of a cavitation bubble. The main purpose of my PhD research is to create and observe such a bubble in a highly controlled environment, and to understand how its energy is distributed into the different collapse phenomena. Such understanding would help not only to attenuate cavitation-induced damage, but also to harvest the power of these bubbles in beneficial applications such as in medicine or microfluidics. The work is mainly experimental and includes measurements of highly spherical bubbles in zero-gravity conditions taken aboard ESA parabolic flights, which are great fun. EPFL is a thrilling environment to conduct research. A PhD is extremely challenging – anyway, it was never meant to be easy – but EPFL's outstanding facilities, international nature and the vibrant social activities are truly motivating. EDME is a rewarding program and provides significant support for designing a solid research plan. I particularly enjoy

the informal EDME PhD symposia organized a couple of times every year, which give an excellent opportunity to meet other students outside your own lab, learn what they do and hang out!

Dr. Outi Supponen, PhD thesis in the Laboratory for Hydraulic Machines



Therapeutic solutions in biomechanical orthopedics

The knee is an essential joint of the lower extremity playing important role in our body kinetic chain. Articular cartilage is an avascular biphasic tissue covering load bearing joint surfaces and helps them to glide smoothly over each other. Cartilage homeostasis can be modulated under loading through induced spatiotemporal stress, strain, fluid pressure and velocity fields. I am a third year PhD student in the Laboratory of Biomechanical Orthopedics (LBO) working on mechanobiology of cartilage. My research is devoted to understanding the role of mechanical environment on biophysical response of chondrocytes (the cells forming the cartilage). This is an interdisciplinary project in which I integrate the modeling and optimization results with mechanical and biological experiments. To have contribution to find therapeutic solutions for the patients is the most rewarding aspect of the research in LBO. Particularly, I am glad that I have the opportunity to be a part of a multidisciplinary research group collaborating with biologist, surgeons and bioengineers. In addition, EPFL infrastructure makes it easy to access all required facilities and resources to develop your research plan and enrich your scientific outlook. Last but not least, being a member of EPFL community has also broaden my social interactions thanks to its international and multicultural environment.

Naser Nasrollahzadeh
PhD student in the Laboratory
of Biomechanical
Orthopedics

Numerical investigations on adhesive and abrasive wear

Wear is the removal of material from solid surfaces and it is a phenomenon widely present, both in nature and in artificial objects and at all scales. Its relevance is evident in many engineering applications, like in the durability of manufactured objects, but surprisingly the topic triggered scientific interest only in the last century. This is partly due to the complexity of the phenomenon. In fact, wear intertwines with other phenomena that take place at the interface between solids, like friction, revealing a high complexity that is responsible for the lack of a deep physical understanding of wear. By adopting numerical simulations, in my PhD research I aim at isolating the fundamental mechanisms that govern the two most common forms of wear (adhesive and abrasive wear), gaining meaningful insights on their physics.

This cutting edge research is possible thanks to the EDME program and the resources available at EPFL. In fact, high-performance computers are available for researchers and during the PhD it is possible to attend several classes, tailoring the choice according to one's needs. The participation to international conferences and summer schools is also highly encouraged. Personally, I am enjoying a lot being part of an international environment and having the possibility of meeting cultures which are different from mine. I am really excited by my experience here and I am looking forward for what is to come in the next years.

Enrico Milanese
PhD student in the Computational Solid Mechanics Laboratory

Thesis Directors in Fluid Mechanics		
Prof. Christophe ANCEY	Head of the environmental hydraulics laboratory (LHE)	lhe.epfl.ch/
Prof. François AVELLAN	Head of the laboratory for hydraulic machines (LMH)	lmh.epfl.ch/
Dr. Mohamed FARHAT	Senior scientist (MER) at the laboratory for hydraulic machines (LMH)	lmh.epfl.ch/
Prof. François GALLAIRE	Head of the laboratory of fluid mechanics and instabilities (LFMI)	lfmi.epfl.ch/
Prof. Fernando PORTE-AGEL	Head of the wind engineering and renewable energy laboratory (WIRE)	wire.epfl.ch/
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Prof. Karen MULLENERS	Head of the unsteady flow diagnostics laboratory (UNFOLD)	unfold.epfl.ch/
Prof. Elisa MATIOLI	Head of the power and wide-band-gap electronic research laboratory (POWERLAB)	powerlab.epfl.ch/
Prof. Dolaana KHOVALYG	Thermal Engineering for the Built Environment Laboratory (TEBEL)	tebel.epfl.ch/

Thesis Directors in Solid Mechanics		
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Prof. Demetri PSALTIS	Head of the optics laboratory (LO)	lo.epfl.ch/
Prof. Dimitrios LIGNOS	Head of the Resilient Steel Structures Laboratory (RESSLAB)	resslab.epfl.ch/
Prof. Annalisa BUFFA	Head of the Prof Buffa Group (UPBUFFA)	mns.epfl.ch/
Prof. Roland LOGE	Head of the laboratory of thermomechanical metallurgy - PX group Chair (LMTM)	lmtm.epfl.ch/
Prof. John KOLINSKI	Head of the Engineering Mechanics of Soft Interfaces laboratory (EMSI)	emsi.epfl.ch/
Prof. Guillermo VILLANUEVA	Advanced Nano-electromechanical Systems Laboratory (NEMS)	nems.epfl.ch/
Prof. Pedro M. REIS	Flexible Structures Laboratory (FLEXLAB)	flexlab.epfl.ch/
Prof. Dario FLOREANO	Laboratory of Intelligent Systems (LIS)	lis.epfl.ch/

Thesis Directors in Geomechanics		
Prof. Lyesse LALLOUI	Head of the laboratory of soil mechanics (LMS)	lms.epfl.ch/en
Prof. Laurent VULLIET	Professor at the laboratory of soil mechanics (LMS)	lms.epfl.ch/en
Prof. Brice LECAMPION	Head of the geo-energy laboratory (GEL)	gel.epfl.ch/en
Prof. Marie VIOLAY	Head of the Laboratory of experimental rock mechanics (LEMR)	lemr.epfl.ch/

Thesis Directors in Biomechanics		
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Prof. Selman SAKAR	Head of the MicroBioRobotic Systems Laboratory (MICROBS)	microbs.epfl.ch/
Prof. Alexandre PERSAT	Microbial Mechanics Laboratory (UPPERSAT)	persat-lab.epfl.ch/
Prof. Auke IJSPEERT	Biorobotics Laboratory (BIROB)	biorob.epfl.ch/

Application Process

You need to complete and submit the EPFL doctoral school online application form on the following link:
<https://phd.epfl.ch/application>

Beforehand, we encourage you to surf the EPFL doctoral school and EDME program webpages:
<https://phd.epfl.ch/EDME>

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