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Analysis of the Patent Portfolio of the ETH Domain

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Management Summary

Research, development and innovation are at the core of Switzerland's competitiveness. Technological progress is the key trend currently discussed in many industrial countries and increasingly the question regarding «the return on investment» comes into the debate. Although the partly public-financed basic research of the ETH Domain can never be directly associated with concrete results in terms of products and services, it can, however, be assessed in terms of patents. Due to the structured process of patent applications and grants, and the massive amounts of data and information available in each patent application, patents are considered one of the most promising area of analysis.

The present study is entirely devoted to the patents indicator, but it is obvious that only that part of the ETH Domain's innovation performance is covered which is marketable and can and should therefore be patented. Further innovation of the ETH Domain for example in public goods or teaching methodology cannot be covered.

National and international comparison with focus on patent quality

Traditionally, patent analyses focused on the number of patents per institution or company, there was no classification of the relevance of each invention - each patent is counted. For the first time, the application of big-data methods allow for a completely new use and analysis of patents where patent quality is evaluated for each individual patent worldwide. In addition, the patent activities can be analysed for the specific technology focus areas of the ETH Domain.

The study at hand applies these new concepts and scientific approaches to answer the following questions:

- How significant is the ETH Domain in specific technologies for the science and research landscape in Switzerland?

- How significant is the ETH Domain in world class patents in specific technologies for the science and research landscape in Switzerland?

- How does the ETH Domain compare to the most important international research institutions in the selected technologies?

The analysis was done for 17 specifically defined technologies and compares the research quality in terms of patents of the ETH Domain to other research institutions and the industry sector in Switzerland, and to a selection of ten international research institutions among the most important ones.

17 technologies defined, covering two thirds of all ETH Domain patents

1037 Patents were owned by the ETH Domain at the end of 2017. Based on this sample, the technologies were defined in a multi stage process over the course of several months with the participation of experts from each participating Institution of the ETH Domain, the ETH Board, the Swiss Federal Institute of Intellectual Property, BAK-Economics and EconSight. Technologies were proposed and associated patents calculated using approximation methods, and refined to a point where 17 technologies were defined according to the following criteria:

- A significant share of the total patent activities of the ETH Domain should be covered
- The technology foci of each participating institute should be included
- The strategic focus areas of the ETH Domain should be covered

671 of the ETH-Patents were identified for the 17 technologies as active patents in the year 2017. The remaining 366 patents come from an extremely wide range of research areas making it impossible to group them into technologies which can be compared on a national and international level. However, two thirds of all patents were identified and associated with the 17 technologies. Some patents are attributed to more than one technology and are therefore counted more than once. This intended overlaps between technologies leads to a total of 910 patent counts in the aggregation of the 17 technologies.

A third of all analysed ETH Domain patents are world class patents

The 17 technologies can be broadly categorized into digital/data technologies, manufacturing/materials, broad systems, life sciences and energy. The chart below shows the technologies and the identified patents and world class patents.

Tab. 1-1 Technology profile of the ETH Domain

Technology Field	Technology	Total Patents	World class patents	Patenting Efficiency	ETH Domain Rank in CH
Digital / Data	Security Elements	63	17	27%	4
Digital / Data	Quantum Technologies	22	7	32%	1
Digital / Data	Digital Image Analysis	81	19	23%	1
Manufact./Materials	Advanced Materials	100	57	57%	1
Manufact./Materials	Nanostructures	132	48	36%	1
Manufact./Materials	Additive Manufacturing	34	0	0%	- *
Systems	Mass Spectroscopy	59	12	20%	2
Systems	Drones	11	8	73%	1
Systems	Radiation Detectors	29	16	55%	1
Life Sciences	Biosensors, Lab-on-a-Chip. Bioprinting	53	16	30%	2
Life Sciences	Wearables Bionics	40	9	23%	1
Life Sciences	Radiation Diagnosis and Therapy	50	22	44%	1
Life Sciences	Protein Engineering	122	40	33%	4
Life Sciences	Drug Discovery Systems Biology	19	1	5%	7
Life Sciences	Pharmaceutically active Subs.	24	1	4%	45
Energy	Organic Perovskite Tandem Photovoltaics	43	24	56%	2
Energy	Waste Water, Biomass, Carbon Capture	28	14	50%	2
Total		910	311	34%	

* not ranked, no world class patent in this technology
Source: BAK Economics, IGE, PatentSight

A third of all analysed patents can be considered world class patents. World class patents are the 10% of the highest rated patents in each technology worldwide. The patent rating is based on a new big-data approach which identifies, evaluates and rates each patent worldwide by technological relevance (based on third party citations of each patent) and market coverage (number of countries covered by the patent protection). The main focus of this analysis is on world class patents.

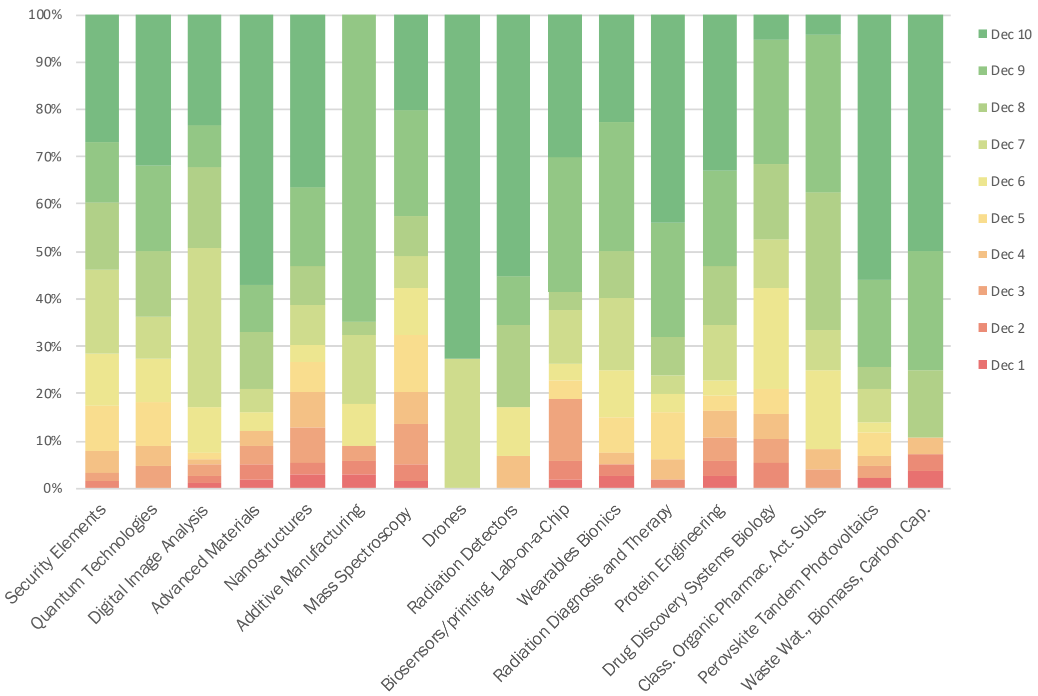
National comparison - ETH Domain in first place in 8 out of 17 technologies compared to Swiss companies and other research institutions

The national comparison of the ETH domain with Swiss companies in world class patents shows that the ETH Domain ranks in first place in 8 out of 17 technologies and in the top five in six additional technologies (Tab. 1-1). Compared to companies and other research institutions in Switzerland the ETH Domain owns the most world class patents in a wide range of technologies such as quantum technology, image analysis, radiation diagnosis and therapy.

Patent structure is of very high quality

Structuring the patent portfolio into deciles, from the top-10% to the bottom-10%, it can be shown that the patent structure of the ETH Domain in each technology is of above average quality. In 12 technologies 50% of the patents are of very high quality and in the case of the energy technologies, drones and radiation detectors, the top 2 deciles account for more than 70% of the patents. Furthermore, only very few patents can be found in the low-quality deciles. This clearly demonstrates the above average quality of the ETH Domain patent portfolio.

Chart 1-1 Patent structure of the ETH Domain by technology and quality, 2017



Source: BAK Economics, IGE, PatentSight

International comparison – focus on world class patents

The international analysis is done for world class patents only. Patent analyses based on total patent counts generally lead to unsatisfactory results because of distorting effects due to country-specific differences in the patenting systems. For example, intellectual property in Japan is traditionally patented much earlier than in other countries. In China, researchers are incentivized to patent as much as possible in order to increase the relevance of China as a research location. The simple measurement of patent activity in terms of new registrations exaggerates the importance of certain countries and distorts the overall picture.

The table below shows total patents and world class patents for a selection of 10 international research institutions. These institutions own a total of almost 42’000 patents in the selected 17 technologies. The Chinese Academy of Sciences alone owns 19’000 of these patents and distorts the analysis due to the political pressure behind the Chinese patent activities.

Tab. 1-2 Patent overview for 10 international research institutions and the ETH Domain, world class patents and total patents, 2017

Institution	Total patents	World class patents	Patenting efficiency
Chinese Academy of Sciences	19’124	441	2%
University of California System	5’164	949	18%
Tsinghua University	4’968	531	11%
CNRS	2’925	319	11%
MIT	2’308	868	38%
Fraunhofer	1’820	184	10%
Stanford University	1’728	255	15%
Harvard	1’563	807	52%
Japan Science and Technology Agency	1’158	110	9%
ETH Domain	910	311	34%
University of Oxford	431	142	33%

Source: BAK Economics, IGE, PatentSight

ETH Domain with third highest patenting efficiency

Nevertheless, the general comparison of total patents and world class patents provides some valuable insights. Although total patenting differs quite substantially between the institutions, they are comparatively close in terms of world class patents. Consequently, the patenting efficiency (share of world class patents in total patents owned) varies among the institutions. The ETH Domain has the third highest patenting efficiency behind Harvard and MIT.

ETH Domain among the leaders in more than one third of all technologies analysed

The international comparison of the ETH Domain with some of the most renowned universities and research institutions worldwide shows that the ETH Domain has clear advantages in system technologies such as mass spectroscopy, drones and radiation detectors. It is also ahead in security elements where there are almost no viable competitors. Another strong development can be observed in perovskite tandem photovoltaics. Overall, the ETH Domain is among the leaders in more than one third of all technologies analysed.

ETH Domain ahead of European institutions

The international comparison shows the wide range of high quality patents at the US institutions MIT, Harvard, and California while the European institutions are significantly behind those in in the chosen technologies. The ETH Domain is positioned ahead of the European institutions but clearly behind those in the US. It has to be noted that both Chinese institutions are well positioned in many technologies. Furthermore, their patenting activities in most areas started less than 10 years ago. Today they are ahead of the European institutions.

The following table provides an overview of the international results. The heat map is organized horizontally and labels the institutions with the highest number of world class patents within a technology in green colour gradients and the institutions with the lowest numbers in red colour gradients. Vertically the number of similarly coloured cells indicate the number of high rankings (green) and low rankings (red) per institution. The large number of green fields shows the leading positions of the US institutions in the majority of technologies.

Tab. 1-3 International comparison of world class patents per technology, 2017

	ETH Domain	CNRS	Fraunhofer	Oxford	Stanford	Harvard	MIT	California	Japan STA	Chinese AS	Tsinghua
Security Elements	17	0	58	0	0	1	0	1	0	0	0
Quantum Technologies	7	6	1	6	3	21	39	23	3	12	3
Digital Image Analysis	19	7	29	19	22	5	19	35	4	17	35
Advanced Materials	57	60	15	7	23	58	126	151	28	138	173
Nanostructures	48	76	21	22	36	147	203	260	44	95	209
Additive Manufacturing	0	3	9	0	5	70	47	13	1	8	3
Mass Magnet Spectroscopy	12	6	6	7	10	11	12	18	3	12	19
Drones	8	0	0	1	1	0	4	0	0	0	1
Radiation Detectors	16	0	2	0	0	0	4	1	1	4	12
Biosensors, Lab-on-a-Chip. Biopr.	16	19	5	10	22	123	61	74	7	8	9
Wearables Bionics	9	0	5	1	6	11	32	24	1	3	0
Radiation Diagnosis and Therapy	22	7	2	3	15	7	16	33	0	6	25
Protein Engineering	40	86	10	47	86	288	218	232	15	25	12
Drug Discovery Systems Biology	1	1	0	0	15	42	28	23	0	0	1
Pharmaceutically active Subs.	1	12	0	1	0	15	4	11	0	5	0
Perovskite Tandem Photovoltaics	24	10	6	16	4	6	13	17	0	11	2
Waste Water, Biomass, Carb. Cap.	14	26	15	2	7	2	42	33	3	97	27
Total world-class patents	**311**	**319**	**184**	**142**	**255**	**807**	**868**	**949**	**110**	**441**	**531**

Source: BAK Economics, IGE, PatentSight

ETH Domain joint research projects, inventions, and inventors in high demand

The ETH Domain is very active in joint research projects with industry or other research institutions. 376 co-owned patents stem from joint research projects. The ETH Domain participated in joint research for an additional 479 patents which are solely owned by the partnering company or institution. Furthermore, ETH inventions are highly relevant. 1945 companies and research institutions worldwide cite ETH Domain inventions in 5041 third party patents. Former ETH Domain inventors remain very active once they go on to do industry research in Switzerland. 3801 company patents list at least one inventor who has worked and patented for the ETH Domain before joining the respective company.

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1 Introduction

The ETH Domain[1], just like any other (partly) public-financed institution, is under constant public and political observation regarding the sensible spending of these funds. Increasingly the question regarding «the return on investment» comes into the debate. While basic research can never be directly associated with concrete results in terms of products and services, it can, however, be assessed in terms of scientific publications and patents. Patents are currently the most promising area of analysis because of the large number of intellectual property worldwide, the structured process of patent applications and grants, and the massive amounts of data and information available in each patent application.

Although the present study is entirely devoted to the patents indicator, it is obvious that only that part of the ETH Domain's innovation performance is covered which is marketable and can and should therefore be patented. Further innovation of the ETH Domain for example in public goods or teaching methodology cannot be covered.

Traditionally, patent analyses focused on the number of patents per institution or company, there was no classification of the relevance of each invention - each patent is counted. First-time applied big-data methods allow for a completely new use and analysis of patents where patent quality is evaluated for each individual patent worldwide. In addition, the patent activities can be analysed for the specific technology focus areas of the ETH Domain.

The study at hand applies these new concepts and scientific approaches to answer the following questions:

- How significant is the ETH Domain in specific technologies for the science and research landscape in Switzerland?

- How significant is the ETH Domain in world class patents in specific technologies for the science and research landscape in Switzerland?

- How does the ETH Domain compare to the most important international research institutions in the selected technologies?

The analysis was done for 17 specifically defined technologies and compares the research quality in terms of patents of the ETH Domain to other research institutions and the industry sector in Switzerland, and to a selection of ten international research institutions among the most important ones.

[1] ETH Zürich, EPFL, PSI, Empa, Eawag and WSL

2 Approach and Methodology

The approach applied consists of several steps and combinations of methods and definitions that are explained in this chapter.

1. Definitions

   In the first step of the project the relevant technologies are defined, the national and international research Institutions and companies to be compared are identified and grouped, and the applicable worldwide patents are identified, consolidated and mapped to technologies, countries and institutions.

2. National comparison of the ETH Domain patenting activities

   In this step, the significance of the ETH Domain research in patent activities in selected technologies is illustrated and compared to the patenting activities of companies and other research institutions in Switzerland. All of Switzerland's patents are identified and assigned to each of the chosen technologies and either institutions or companies. The analysis will be done for total patents and world class patents.

3. International comparison of the ETH Domain patenting activities

   In this step the ETH Domain will be compared to some of the most renowned universities and research institutions worldwide. The analysis will be done for world class patents in a time series from 2000-2017.

4. Additional direct and indirect patenting activities associated with the ETH Domain

   In this last step, further patent information regarding named inventors as well as national and international citations is used to identify additional direct and indirect patenting activities associated with the ETH Domain

2.1 Definition of Technologies

Most technology analyses either use broad technology fields or very specific patent classes. Both concepts have advantages and shortcomings. Technology fields, mostly based on the established WIPO (World Intellectual Property Organisation) technology fields[2], structure the patent landscape in broad categories and are helpful for wide ranging analyses and the identification of main research foci of countries. When applied to individual institutions or companies research portfolios, this approach often fails to identify and describe the specific technologies and their dynamics. Patent

[2] Audio-visual technology, Telecommunications, Digital communication, Basic communication processes, Computer technology, IT methods for management, Energy, Semiconductors, Optics, Measurement, Analysis of biological materials, Control, Medical technology, Handling, Machine tools, Engines pumps turbines, Electrical machinery apparatus, Textile and paper machines, Other special machines, Thermal processes and apparatus, Mechanical elements, Transport, Organic fine chemistry, Biotechnology, Pharmaceuticals, Macromolecular chemistry polymers, Food chemistry, Basic materials chemistry, Materials metallurgy, Surface technology coating, Micro-structural and nano-technology, Chemical engineering, Environmental technology, Civil engineering, Furniture, games, Other consumer goods

classes on the other hand are at the core of patent classification system but are too technical and often too specific for strategic analysis.

This study uses a “middle ground” between both concepts by defining a set of specific technologies to capture the technological activities of the ETH Domain in the best possible way. Each technology is based on a set of patent classes.

The technologies were defined in a multi stage process over the course of several months with the participation of experts from each participating Institution of the ETH Domain, the ETH Board, the Swiss Federal Institute of Intellectual Property, BAK-Economics and EconSight. Technologies were proposed and calculated using approximation methods, and refined to a point where the following 17 technologies were defined according to the following criteria:

- A significant share of the total patent activities of the ETH Domain should be covered
- The technology foci of each participating institute should be included
- The strategic focus areas of the ETH Domain should be covered

Tab. 2-1 Technology profile of the ETH Domain

Technology Field	Technology
Digital / Data	Security Elements
Digital / Data	Quantum Technologies
Digital / Data	Digital Image Analysis
Manufacturing / Materials	Advanced Materials
Manufacturing / Materials	Nanostructures
Manufacturing / Materials	Additive Manufacturing
Systems	Mass Spectroscopy
Systems	Drones
Systems	Radiation Detectors
Life Sciences	Biosensors, Lab-on-a-Chip. Bioprinting
Life Sciences	Wearables Bionics
Life Sciences	Radiation Diagnosis and Therapy
Life Sciences	Protein Engineering
Life Sciences	Drug Discovery Systems Biology
Life Sciences	Classic Organic Pharmaceutically Act. Subs.
Energy	Organic Perovskite Tandem Photovoltaics
Energy	Waste Water, Biomass, Carbon Capture

Source: BAK Economics, IGE, PatentSight

2.1.1 Overview and short descriptions of the identified technologies

The following chapter provides an overview and short descriptions for each technology. In addition, an illustrative example from the patent portfolio of the ETH Domain was chosen and portrayed for each technology. Longer descriptions of the technologies as well as the relevant patent classes identified for each technology can be found in the annex to this study.

Security Elements

Security elements encompass a wide range of security measures that are used to protect information and final products against threats. It is crucial for companies to be able to guarantee their customers the authenticity, security and genuineness of their final products. This includes the production of banknotes, passports and medicine packaging. In IT, the key problem is ensuring that the access to data is authorized as well as guaranteeing that the use of the data is secure. To achieve this, hardware and networks have to be protected with firewalls, anti-virus software, encryption and other measures.

ETH Domain security elements patent on end-to-end encryption

One of the most widely used encryption methods is the https internet protocol to encrypt the transfer of data between servers. Data transfers on the internet usually take different routes via several servers – which is the nature of a decentralized system. Https is very effective in securing the transfer of data between these servers, but it is not very effective in securing the data on the server, because by the nature of the https-protocol files are decrypted on the server receiving them where they can be intercepted. Furthermore, https relies on certificates which can be forged.

The ETH Domain has tackled the problem and developed an end-to-end encryption system whereby the information is encrypted on the computer of the user and never decrypted until it reaches the final destination where it can be decrypted using a password provided. The data is thereby packaged as an HTML document, which can be distributed through regular e-mail, cloud services, or any other means, and decrypted using any modern internet browser, without installing any other software on the recipients' computer. The inventors are currently in discussion with major internet companies to license the technology.

Quantum Technologies

The control of individual quantum systems has opened the door to new quantum technologies that are often described as the second quantum revolution. These new quantum technologies are expected to become innovation drivers in the coming decades. Potential applications include extremely rapid computers (quantum computing), intercept-proof communications (quantum cryptography) and hyper-sensitive measuring methods (quantum sensing). While the development of quantum computers is still in its early stages of development, quantum cryptography and quantum sensing are already close to commercialisation and products have started to appear.

ETH Domain quantum technologies patent on single photon detectors

The single-photon detectors developed at the ETH Domain offer unique advantages with their high sensitivity, dynamic range, and speed. One example of their application in photonics and semiconductor devices is the development of ptychographic tomography for imaging at the nanoscale level. Ptychography is a lensless imaging method and provides a unique combination of contrast, high-resolution and sensitivity, which allows for extremely detailed 3D maps of the sample electron density. An important application of the technology is the inspection of microchips. Since research, design and production of integrated circuits take place in different areas of the world, it is currently a matter of trust whether the actual chip was produced according to specifications or if hidden changes in the design were made. Single-photon detectors in combination with ptychography would be able to detect differences between design and production. This is for example of interest for the military or security agencies.

Another application is expected to be in microchip design. Should Moore's law, which states that the number of transistors in a dense integrated circuit doubles about every two years, hold for the future, extreme nanoscale production would be required. In photolithography, which is the technique currently used for chip manufacturing, the circuit master designed on a photomask is replicated on silicon-wafers. The major risk is an undetected small printing error on the photomask. Highly sensitive single photon detectors are able to inspect the photomask design in detail. One could compare the complexity and challenge of the task to finding a coin hidden somewhere in Switzerland within just a few hours.

There are competing activities worldwide but only the ETH Domain is able to provide the full range of the components, such as the source and the method in addition to the single photon detector technology. A spin-off has been set up for further applied research and commercialization of the technology.

Digital Image Analysis

Image analysis describes the extraction of meaningful information from images. The applications of digital image analysis are continuously expanding and the technology is now used in countless areas of science and industry including astronomy, defense, machine vision, medicine, robotics and many more. In the medical field, image analysis plays an important role in tracking diseases and assessing treatment effects. Digital image analysis in the form of facial recognition is also used to improve security standards. Moreover, image analysis plays a crucial role for the development of autonomous vehicles, since these vehicles need to be able to recognize driving patterns of human drivers and other autonomous cars.

ETH Domain digital image analysis patent on stereoscopic postproduction

Three-dimensional stereoscopic television, movies, and games have been gaining more and more popularity both within the entertainment industry and among consumers. An ever increasing amount of content is being created, distribution channels including live broadcast are being developed, and stereoscopic monitors and TV sets are being sold in all major electronic stores. With novel generations of autostereoscopic and multi-view autostereoscopic displays, even glasses-free solutions become available to the consumer. However, the task of creating convincing yet perceptually pleasing stereoscopic content remains difficult. This is mainly because postprocessing tools for stereo are still underdeveloped, and one often has to resort to traditional monoscopic tools and workflows, which are generally ill-suited for stereo-specific issues. To overcome those limitations, a novel concept based on 3D light fields for stereoscopic postproduction has been proposed by the ETH Domain. The technology introduces an effective and practical solution to key issues arising in today's stereoscopic content generation and post-production, for computer-generated content as well as live-action content.

Advanced Materials

Advanced materials offer superior properties such as toughness, hardness, durability and elasticity. Nanomaterials are today common additives in many different types of products such as paints, cosmetics, textiles, sports equipment, electronic and medtech products. At the same time, smart polymers are specifically engineered for targeted drug delivery as researchers employ them to control the release of drugs. Graphene is one of the lightest, strongest, thinnest, best heat- and electricity-conducting materials known. However, the commercialization of graphene-based materials is still in its infancy. Another class of ultra-high performance functional nano-porous materials are aerogels - extremely light-weight and great thermal insulators that can be used in many applications such as thermal and acoustic high-performance insulation, adsorbents, filters, catalyst supports, and electrodes for electrochemical energy storage.

ETH Domain advanced material patent on aerogels

One of the most promising applications of aerogels is the thermal insulation of building envelopes, where the demand for insulation rises rapidly due to tightening building codes imposed by new energy policies in many industrialized countries. The use of aerogels has several advantages over the traditional insulation method with polystyrene foam: they are water-repellent (hydrophobic) but still water-vapor permeable and thus breathable and therefore can prevent condensation. They are mineral-based and non-toxic, which facilitates recycling or disposal, and most importantly they insulate more effectively requiring much thinner layers than traditional polystyrene foam – roughly half the thickness for the same performance.

As with other advanced materials the biggest technical challenge is the often complex and costly production process. The majority of aerogels sold today are produced by extracting the liquid component of a gel through supercritical drying using large quantities of CO2 and time consuming batch extraction and drying steps. This allows the liquid to be slowly dried off without causing the solid matrix in the gel to collapse from capillary action and hence to produce perfect aerogels.

The ETH Domain has found a way to greatly reduce the required chemicals, to shorten the drying period and to increase flexibility of the production process using a different process, so-called ambient pressure drying. Aerogels in granular form are created by evaporative drying. This "one-pot" process greatly reduces the amount of chemicals and solvents required, while massively shortening the overall sol-gel and drying period. Instead of rinsing out the liquid in the initially prepared gel and replacing it with another solvent (e.g. with CO2 which even makes the "old" and time-consuming drying process possible), only a small fraction of a new catalyst containing liquid has to be added to react briefly before drying. This reduces the overall solvent consumption and process time by more than half. First products for insulating historical façades are already on the market and industrial scale production as well as integration into products for various applications are expected within the next few years.

Nanostructures

Nanostructures are defined as structures that range between 1 nanometer (molecular scale) and 100 nanometers in at least one dimension. Semiconductor nanostructures, especially quantum dots, display a broad range of unique optical and electronic properties. Therefore, quantum dots are used in circuit boards, transistors, quantum computing and many other applications. Nanostructured materials are also employed in food science where nanostructures such as polymeric nanoparticles, liposomes, nanoemulsions, and microemulsions are used. These materials can help to improve solubility, increase bioavailability and food shelf life, facilitate controlled release, and protect bioactive components during manufacture and storage. However, there remain concerns about potential risks to human health of nanostructures which need to be addressed by further research.

ETH Domain nanostructures patent on thin-film layers

One method involving nanostructures is the fabrication of thin-film layers which range from fractions of a nanometer to several micrometers in thickness. Applications of thin-film layers range from semiconductors and coatings to battery storage systems or very thin solar cells.

The ETH Domain has applied thin-film methods to solar cells where thin-film technologies are widely expected to reduce the cost of solar cells. The so-called CIGS solar cell is manufactured by applying a very thin layer of copper, indium, gallium and selenide on glass or plastic backing. The ETH Domain managed to improve the manufacturing process of bringing these four elements together on a flexible layer.

The ETH Domain thin-film patents allow for the production of cheaper, more flexible and more effective thin-film solar cells as an alternative to traditional silicon based solar cells. For several years the ETH Domain held the world record in efficiency of a flexible solar cell. Currently thin-film solar cells are still twice as expensive as standard solar cells, but wherever the flexibility is required, the thin-film solar cell has clear advantages. The thin-film layers allow for the production of very flexible cells that can be placed on roofing tiles and follow the curves instead of simply mounting flat and thick solar cells on top of the tiles. The ETH Domain has exclusively licensed the technology.

Additive Manufacturing

Additive Manufacturing subsumes production technologies by which products are constructed from sequential layers of material. Additive manufacturing complements conventional production processes, enabling designers and engineers to enhance existing process chains, as well as allowing new opportunities for production. The technology is increasingly being used beyond its initial use as a process for concept modelling and rapid prototyping in manufacturing. The possible fields for application of this technology are widespread, ranging from production equipment (tools and machines) to consumer goods to health care products and even tissue engineering.

ETH Domain additive manufacturing patent on 3D tissue engineering

Traditionally, pharmaceutical companies have relied on 2D plastic petri dishes to conduct in vitro tests. Within the past decade, however, a revolution has begun in cell biology. Researchers now recognize the importance of a 3D environment for capturing accurate cell behaviour. To that end, 3D cell culture technologies have emerged that offer scientists more precise tools for preclinical studies of drug candidates, and specimens for assay validation – all the while reducing or replacing animal trials. The cross-platform 3D Bloom method is unique in that it can be used to make micro tissues of virtually any cell type. After mixing two proprietary 3D Bloom compounds in the presence of cells, there is a rapid crosslinking effect that organizes a group of cells into a 3D structure. The cells interact with each other and their surroundings in a way that mimics the behaviour of tissues within the human body. An ETH Domain spin-off founded in 2015 is working on the further development and commercialisation of the technology.

Mass Spectroscopy

Mass spectrometers enable scientists to analyse the composition and origin of a material by quantifying its atoms and molecules. It possesses key advantages including a better sensitivity than most other analytical techniques. Mass spectrometry is used in many different applications in biology, chemistry, physics and clinical research. Specific applications of mass spectrometry include drug testing and discovery, food contamination detection, pesticide residue analysis, isotope ratio determination, and carbon dating.

ETH Domain mass spectroscopy patent on laser ablation cells

An interesting patent of the ETH Domain improves the setup of the sampling cell required for high-resolution imaging mass spectroscopy which increases the sensitivity of that technique. Laser ablation is the process of removing and evaporating material from a solid object by bombarding it with a laser beam. The gaseous sample is then transported into the spectrometer for analysis by helium and argon.

Normally the samples are quite small, especially biological samples, and a successful analysis heavily depends on transporting as much material fast as possible from the sample into the spectrometer in order to achieve a high sensitivity. The ETH Domain has greatly improved the whole process by optimizing the geometrical setup of the laser ablation cell.

Optimising the laser ablation cell means that more sample material is introduced to the mass spectrometer and the analysis is much more sensitive. Thus, the sample size required for analysis is greatly reduced. This is important for cell biology, for example cancer tissue. The technique is also important for the analysis of valuable materials such as diamonds where only a very small sample is required for analysis, thus not reducing the value of the object. Laser ablation also offers a near non-destructive approach for the analysis of works of art.

Drones

Drones, more formally known as unmanned aerial vehicles (UAV), are essentially flying robots without a human pilot aboard. While military drones still account for the vast majority of world-wide spending on drones, there are also more and more business applications because drones can perform inspections and gather data quicker, cheaper, and more frequently than people or helicopters can. The impact of drones is also expected to be substantial for the e-commerce and the logistics sector as many companies are currently developing drone delivery services that can deliver goods faster and cheaper to customers.

ETH Domain drone patent on software based safety features

One current focus in drone development is safety, because this is widely regarded as the major regulatory obstacle for commercial and industrial use of drones. Most drones are quadrocopters with four propellers and especially those for private use-lack safety features. They are prone to engine failure, propeller breakage, battery failure, and electric shortages. If this happens, an affected drone falls uncontrollably from the sky and may cause damage and severe injuries – not to mention the loss of payload. Professional drones have certain safety features on board such as redundant propellers, engines or parachutes which also make them heavier and less effective.

The ETH Domain patent allows replacing this additional hardware with a software solution. The invention is an algorithm that allows to steer and land an affected drone in a controlled way. The algorithm even works for drones that only have one working propeller left – something that was not deemed possible several years ago. The software can be implemented in professional drones as well as in drones for recreational use.

The technology is licensed to an ETH Domain spin-off that is currently in talks with major drone producers and has already showcased the technology in an unusual environment – a Broadway show where eight software-equipped drones were part of the choreography and completed almost 400 public shows, including more than 7000 autonomous takeoffs, flights, and landings, in front of an audience of up to 2,000 people per show, all of them without safety nets.

Radiation Detectors

Radiation detectors, also known as particle detectors, are instruments that are employed to detect, track, and measure ionizing particles from radioactive materials, cosmic radiation, or reactions in a particle accelerator. One of the most widely known usage of radiation detectors was for the CERN CMS particle detector, the wider application of the new generation of such innovative detectors (highly sensitive, very low noise, very fast) is mainly targeted at photon (x-ray) detection. The future of this detector technology is to move into the field of medical applications as the high sensitivity allows lower dosages with better resolution.

ETH Domain radiation detectors patent on phase contrast x-ray imaging

Radiation detectors, also known as particle detectors, are instruments that are employed to detect, track, and measure ionizing particles from radioactive materials, cosmic radiation, or reactions in a particle accelerator. While the initial development was performed by the ETH Domain for the CERN CMS particle detector, the wider application of the new generation of such innovative detectors (highly sensitive, very low noise, very fast) is mainly targeted at photon (x-ray) detection. The future of this detector technology is to move into the field of medical applications as the high sensitivity allows lower dosages with better resolution.

Scientists all around the world exploit synchrotron radiation to explore matters and investigate complex mechanisms in life and material science. Synchrotrons, like the Swiss Light Source operated by the ETH Domain, are particle accelerators designed to produce highly brilliant beams of x-ray light. For x-ray imaging in particular, synchrotron based techniques have allowed the creation of images at the nanometer scale with unprecedented quality. To achieve such increases in imaging capability, dedicated optical components (called gratings) have been designed. It was further discovered that the same gratings could be used to obtain better measurements of how x-rays interact with matter. It became possible to provide information on how an object absorbs, phase-shifts, refracts or eventually scatters x-rays. Scientists within the ETH Domain were able to transfer this approach to be used with conventional x-ray sources paving the road to new opportunities for vastly improved x-ray diagnostics.

For more than 100 years, doctors have been taking x-ray images of patients that rely on the absorption of x-rays only, while phase-shift, refraction and scattering effects were ignored. Thanks to the grating technology, these fundamental interactions can now be integrated into the imaging process to provide doctors with a new powerful diagnostic tool that is capable of providing greatly enhanced x-ray images. A start-up company has been founded with the aim of using this grating-based imaging for early breast cancer detection: the new technology will provide significantly better diagnostic results reducing both false positives as well as false negatives. Further potential applications include non-destructive testing or homeland security. The ETH Domain has been pioneering this field and holds the relevant patents in this technology.

Biosensors, Lab-on-a-Chip. Bioprinting

Bioprinting, Biosensors and Lab-on-a-chip are three cutting edge technologies that have the potential to play an important role in the Life Sciences sector in the future. Biosensors are mainly used in the food industry and in the medical field to check the quality and safety of food products and to detect, diagnose and control diseases. Bioprinting combines biotech with 3D-printing technologies in order to create tissue and organs for drug testing. In the future, it might even be possible to print entire organs for transplantation in patients with organ failure. The main application of Lab-on-a-chip (LOC) technology is human diagnostics and DNA analysis, but LOCs can also be applied for the analysis and synthesis of chemicals and, therefore, could be used for a range of industrial applications and environmental monitoring.

ETH Domain bioprinting patent on personalized cartilage transplants

ETH Domain activities in bioprinting help to generate personalized cartilage transplants using a digital 3D model of the transplant and the body's own cells. Cells, extracted from the patient's own body, e. g. from the nose or ear are spawned in the laboratory and mixed with a biopolymer. From this toothpaste-like suspension, a cartilage transplant is created using a 3D bioprinter, which is implanted in the patient during surgery. In this process, the biopolymer is used merely as a form of shaping mould; it is subsequently broken down by the body's own cartilage cells. After a couple of months, it is impossible to distinguish between the transplant and the body's own cartilage. This procedure has significant benefits compared to traditional implants, for instance those made from silicone, as the risk of the body rejecting the implant is much lower. An ETH Domain spin-off is currently pursuing the translation of this technology into clinics and application on human patients.

Wearables Bionics

Wearables are electronics such as activity trackers and smartwatches that can be worn on the body. One of the major features of wearables is their ability to connect to the internet, enabling data to be exchanged between a wide area network and the device. The term bionics describes the application of biological methods to the study and design of engineering systems and modern technology. Promising bionics applications are powered wearables called exoskeletons that work in tandem with the user and that allow for increased strength and endurance. However, most exoskeletons applications are still in an early development stage.

ETH Domain wearable bionics patent on deep brain stimulation

Another research area is concerned with neurostimulation, where electrical stimulation is used to improve the life quality of people who suffer from the loss of sense organs or limbs, chronic pain or diseases such as epilepsy or parkinsons disease. Deep Brain stimulation directly changes the brain activity in a controlled manner via implanted electrodes.

One of the major challenges in the application of deep brain stimulation is the positioning of the electrode in the specific area of the brain which can be very small. A misalignment of just a few millimeters may reduce the effectiveness. Also, the side effects and risks during surgery are significant. The ETH Domain has developed a new array of microelectrodes that can direct the electrical pulses with greater precision and therefore deliver a more targeted treatment.

The new approach uses real time imaging to position the electrode whereas the old approach used a lengthier step-by-step combination of image analysis, better positioning and further image analysis. The innovation allows for a more precise positioning of the electrode which increases the effectiveness and also a faster implantation process which greatly reduces the risks and potential side-effects. A start-up was created to bring the technology to market and it has raised more than 40 million US-Dollars, so far.

Radiation Diagnosis and Therapy

Radiation diagnosis utilizes medical imaging technologies to detect tumors within patients by labelling (highlighting) the tumors with radioactive antibodies. In addition to diagnosis, radiation therapy is one of the most common and important cancer treatment options. The therapy is based on using ionizing radiation to control or kill cancer cells. Within this field, proton therapy is a state-of-the-art method of radiation therapy that allows doctors to treat tumors more precisely while minimizing the damage to the surrounding healthy tissue.

ETH Domain radiation therapy patent on proton pencil beam scanning

Radiation therapy using X-rays is the standard therapy for cancer treatment to either control or kill malignant cells. The Ionizing radiation damages the DNA of the cancerous tissue thus killing the cells. The main task is to aim the beam directly at the tumor. This is done by aiming from several angles so that the most radiation is focused where the beams intersect – ideally the point where the tumor sits. However, surrounding healthy tissue is often also affected because the beam does not differentiate between healthy and cancerous tissue. Also, the strength of a conventional X-ray beam in the body decreases with penetration depth making it even more difficult to protect surrounding tissue.

The ETH Domain has developed the pencil beam scanning approach to proton radiation therapy as an improvement compared to conventional radiation therapy as well as to the existing proton radiation therapy method. The key advantage of proton radiation therapy is that by using protons instead of X-rays the highest dose of radiation can be delivered within the tumor (the so called Bragg peak), and not in the surrounding healthy tissue . As a result less energy is absorbed by healthy tissue reducing potential side effects of the treatment. The pencil beam scanning approach uses 3D-scans to position the beam far more accurately than the traditional method where a simple metal mask was used to direct the proton beams.

Proton therapy is advantageous especially when treating very sensitive tissue areas such as the brain or the eyes. It is also generally used in the treatment of children to reduce long term side effects of the traditional radiation therapy. More than 7000 patients have been treated with the new technology. The ETH Domain as the owner licenses the pencil beam technology and it is now the most widely used system worldwide.

Protein Engineering

Protein engineering describes the process by which novel proteins with desired properties are developed. There are three common methods: knowledge-based mutagenesis (KBM), computational protein design (CPD), and directed evolution (DE). Together, these approaches offer a powerful toolset enabling scientists to manipulate an enzyme's input and output sensitivity. Protein engineering plays a central part in creating smart, stimulus-responsive drugs that can respond appropriately to varying physiological and pathological signals and are, therefore, more effective and cause fewer side effects.

ETH Domain protein engineering patent on antigen-presenting cells to detect cancer

The immune system protects the body against a wide range of infectious diseases and cancer by leveraging the efficiency of immune cells and lymphoid organs. Antigen-presenting cells play an important role in this complex system because they can detect pathogens using receptors, which can be thought of as antennas or feelers. The antigen-presenting cells then initiate an effective response by stimulating B-Cells and T-cells, which in turn produce antibodies or destroy virus-infected cells and tumor cells. However, cancer cells are often able to hide from immune cells, which is why the cancer cells can grow out of control.

One of the major advances in recent years is the CAR T-Cell therapy, which takes patients' own immune cells, genetically reprograms and injects them into the patient to find and attack cancer cells throughout the body. Although very promising with first therapies approved only last year, it can have serious side effects.

The ETH Domain as developed a different approach. The focus is not on the T-cells but on the antigen-presenting cells. Instead of genetically changing the patients' T-cells this approach takes the antigen-presenting cells and manipulates the receptors to better detect cancer cells. It is expected that this therapy has significantly lower side effects and would act as self-vaccination.

Drug Discovery Systems Biology

The process of identifying new medicines - drug discovery- is a complicated, expensive and time consuming endeavour. The well-trodden strategies that have led to the great achievements in drug development have mostly relied on modulating the function of a specific protein target with the effect of alleviating or treating a disease state. A powerful alternative for some diseases is to act at the genetic level. This therapeutic modality is for example particularly relevant for rare diseases where the underlying cause is in most cases caused by an underlying genetic mutation.

ETH Domain drug discovery system patent on viral vector to treat ALS

The workhorse of gene therapy is a modified virus that can deliver in-vivo or ex-vivo exogenous DNA to modify the genetic expression - either through RNA interference, DNA editing, or protein overexpression. While the idea of using gene therapy dates back to the seventies, it is the development and optimization of suitable viral vectors that has allowed gene therapy to pick up pace in the last years and make breakthroughs in the clinic.

The ETH Domain has developed a unique viral vector based on adeno-associated virus (AAV) vectors that is able to deliver in-vivo its genetic payload simultaneously and specifically in neuron and astrocyte cells. Growing evidence shows that these two cellular populations play an important role in many neurodegenerative diseases. However, targeting two cellular populations is not trivial. It cannot simply be addressed by multiple injections that would trigger immune system reactions, or even by combining two cell-specific vectors due to physical constraints that limit the volume that can be injected and the viral dosage. The new vector developed by the ETH Domain elegantly overcomes these hurdles.

The first use for this vector will be used to treat Amyotrophic lateral sclerosis (ALS), a motoneuron disease that affects the voluntary control of muscle activity such as speaking, walking, breathing, and swallowing. The vector will be used to inhibit the expression of a mutant gene (SOD1) associated with ALS in both cell populations. The first results in the laboratory have been spectacular and it is envisaged to proceed with a first in man study with collaboration between the ETH Domain and a clinical center, or otherwise through a spin-off.

Classic Organic Pharmaceutically Active Substances

The category classical organic pharmaceutical active substances encompasses new chemical compounds that will later be used for the development of new pharmaceutical drugs. Newly discovered chemical compounds are often first registered as chemistry patents. An explanation for this is that a patent claim to a chemical compound results in absolute patent protection of that substance, regardless of the intended use. This absolute product protection for chemical compounds or groups of compounds is of considerable economic importance for pharma researchers due to the significant research and development spending and the high risks associated with the development of a new drug.

ETH Domain pharmaceutically substance patent to reduce antibiotics side effects

Treating hospital patients with antibiotics has the adverse side effect of also disrupting their intestinal flora. This happens because the medication wipes out not only the pathogens that caused the disease but also the many bacteria that provide for a healthy intestinal tract. In many cases the Clostridium difficile bacterium starts spreading throughout the gut and releases a toxic substance that can cause life-threatening diarrhea. The standard procedure in these cases is to provide more antibiotics to fight back against Clostridium difficile. But this weakens the intestinal flora even further and the additional treatment with antibiotics proves ineffective.

The reported incidence of Clostridium difficile infection has exploded in the past 15 years and is in the order of hundreds of thousands of cases per year in the USA and Europe. An important factor causing these increases is the emergence of so-called hypervirulent strains that are more resistant to antibiotics and produce more toxin.

The ETH Domain has developed a set of molecules for a completely new treatment approach. Rather than attacking Clostridium difficile directly, this substance binds and inhibits solely the toxins released by the bacterium and thereby prevents the onset of diarrhea. This helps the intestinal flora to regenerate and to get the bacterium under control. The major advantage of this approach is that Clostridium difficile will not develop a resistance to this new substance. Laboratory tests were very promising and safety studies and clinical trials are next on the agenda of a newly founded spin-off company.

Organic Perovskite Tandem Photovoltaics

Organic photovoltaic cells and perovskite photovoltaic cells are two particularly promising areas of solar power research. These new cells have the potential to provide decent power conversion efficiencies combined with low production costs and more flexible applications. However, a big downside of these new photovoltaic cells is that the stability and life span is still much shorter compared to traditional silicon-based cells. Therefore, further research is necessary before perovskite and organic solar cells are able to compete with silicon-based cells on the commercial solar power market.

ETH Domain perovskite patent on new production method to reduce temperatures

The ETH Domain has a long tradition of solar cell research and is considered one of the leading institutions worldwide. Research started in the 1980s with classic solar cells. Work on perovskite cells started in the 1990s when it became clearer that conventional silicon solar cells had reached a point of maturation, with efficiencies around 25% and problems of high-cost manufacturing, heavyweight, and rigidity have remained largely unresolved. The perovskite cell research showed quick results and achieved more than 22% efficiency making them the fastest-advancing solar technology to date.

Apart from efficiency, the biggest challenges for photovoltaic cells lie in stability and cost. In the presence of moisture, the perovskite undergoes rapid decomposition which results in significant decline in performance. However, in 2017 the ETH Domain was able to present large scale perovskite solar modules without degradation over one year, which is considered a major advance. Progress was also made in the production process where the required temperature could be lowered from 500 degrees to 300 degrees by using a specific mix of materials. Since higher temperatures are more difficult to handle, this temperature reduction make it easier and cheaper to produce cells.

Although perovskite cells show promising results, research in classic cells is by no means obsolete because as a combination of both technologies has increased efficiencies even further. These so-called tandem cells have reached more than 25% efficiency. Researchers expect that a tandem design can compensate individual shortcomings and take advantage of the complementary characteristics to enhance the efficiency even further.

Waste Water, Biomass, Carbon Capture

Wastewater treatment, biomass and carbon capture are three technologies that play an important role regarding sustainable development. The process of wastewater treatment is employed to remove contaminants from wastewater to make the water safe for discharge back into the environment. The term biomass refers to organic based materials that are not used for food or feed, but as an energy source either directly via combustion to produce heat, or indirectly after converting it to various sorts of biofuel. Carbon capture describes the process of capturing carbon dioxide from fossil fuel power plants and industrial sites, transporting it to a storage site, and depositing it. The goal of carbon capture is to reduce the release of CO_2 into the atmosphere to counteract global warming.

ETH Domain waste water patent to recover nutrients from urine

The ETH Domain has developed a very promising approach in the area of wastewater treatment to recover nutrients from urine. The idea is that in many developing countries traditional wastewater treatment methods with sanitary facilities and complex water-borne sewage systems do not work because they are very cost intensive and require significant amounts of water – both resources that are scarce in most developing countries. The ETH Domain has developed a dry sanitation system, which is affordable, reduces water pollution, does not require constant maintenance of infrastructure and also recovers nutrients to produce valuable fertilizer.

The patent focusses on the recovery of nutrients such as nitrogen, phosphorus and potassium. Methods for separating specific nutrients from urine have already been developed but the ETH Domain developed a method to separate water from urine, leaving all nutrients as a concentrated solution to be used as fertilizer. The production process involves basically two steps: First, the stored urine, which contains high concentrations of volatile ammonia, has to be stabilized by converting part of the ammonia to a nitrate with the aid of bacteria. In the second step, the liquid is evaporated in a distiller to produce a concentrated nutrient solution and distilled water as by product.

In this case the method was not only patented to generate licensing fees but to ensure that the technology will be widely available at low costs in low- and middle-income countries. The Bill and Melinda Gates Foundation has strongly supported research in the field of nutrient recovery through urine separation and to facilitate development, a spin-off has been created. It is also planned to develop a business model covering the entire production chain from urine collection and treatment to fertilizer distribution.

2.2 Patent Assessment and Rating

Traditional methods of patent analysis focus on the number of patents and the analysis is usually carried out along technology fields or specific patent classes. Apart from the difficulties with broad technology fields as described above, these patent analyses generally lead to unsatisfactory results because of the distorting effects due to country specific differences in the patenting systems. For example, in Japan intellectual property is traditionally patented much earlier than in other countries. In China, researchers are incentivized to patent as much as possible in order to increase the relevance of China as a research location. The simple measurement of patent activity in terms of new registrations exaggerates the importance of certain countries and distorts the overall picture. In addition, there is no classification of the relevance of each invention, as each individual patent is counted. In addition, at most a rough technological classification takes place, which brings no new knowledge. Accordingly, these traditional approaches measure mass rather than class.

In this study a new approach is applied to focus on the quality of research. First-time applied big-data methods allow for a completely new use and analysis of patents. At the same time, the shortcomings of previous patent analyses can be remedied. The analysis is based on a new scientific approach[3] where patent strength is evaluated for each individual patent worldwide and is comprised of two components: the patent activity and the patent quality.

[3] The Patent Asset Index - A New Approach to Benchmark Patent Portfolios, Ernst, H., Omland, N., World Patent Information, Vol. 33, pp. 34-41, 2011

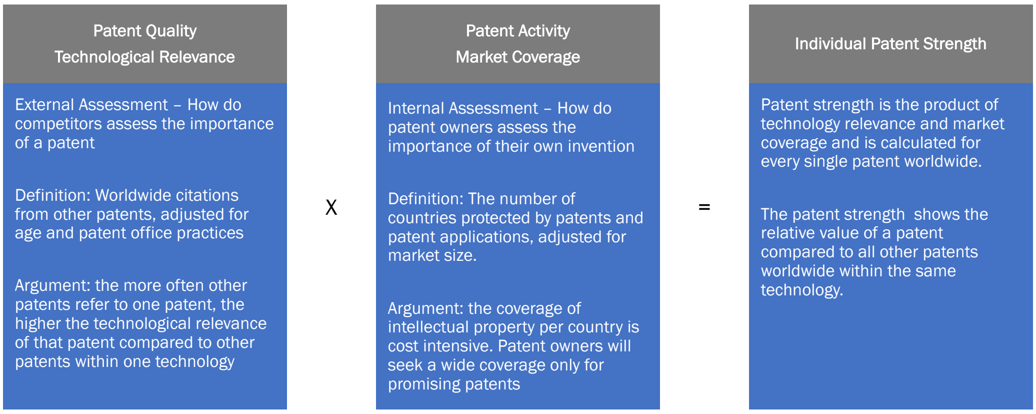
The patent activity corresponds to the market coverage, i.e. the statutory coverage of the patent protection, and shows how companies assess the importance of their own invention (revealed preferences). Since international patent protection is costly, an extensive international market coverage signals that the patent applicant thinks that its patent is promising (self-assessment).

The patent quality corresponds to the relevance of the technology and, based on the references and citations of the patent by third parties, shows how important an invention is in comparison with other patents in the corresponding technology (competitor's assessment).

Taken together, patent quality and patent activity comprise the overall evaluation of the patent or patent portfolio and can be evaluated according to the widest possible variety of criteria, in particular according to specific technologies.

The result is a rating in deciles where the top 10% patents in the world in every technology are being defined as world class patents. The share of world class patents in total patents held by a specific institution can be interpreted as the degree of research effectiveness.

Chart 2-1 Measuring patent strength – technological quality and market coverage



Source: BAK Economics, IGE, PatentSight

Citations are adjusted for patent age. Very young patents (2 years from publication) which by definition cannot have citations are rated with average citations of the institution. Although citations are an external assessment of an individual patent, they can be indirectly influenced by the applicant via the choice of language of the patent application. Patents in German, French, Japanese or Korean language are cited less often than patents in English. Therefore, an applicant can increase the potential of an application to be read (or not read) with an appropriate patent filing strategy.

Market coverage can also be influenced by the applicant to a certain extent by extending the coverage to a wide range of countries. However, this is very cost intensive and the data show that even major companies do not follow this strategy. Nevertheless, market coverage changes over time. A typical PCT (Patent Cooperation Treaty) patent application, which provides a unified procedure for filing applications in its contracting states, starts out with a large number of countries. After 30 months the national application phase starts with fewer countries, followed by even fewer grants. Usually, first citations received during the examination phase provide a first indication of interest in the patent and this determines the number of countries chosen for the national application phase.

In general, technological relevance is more important than market coverage for determining individual patent strength. Market coverage is usually the consequence of technological relevance and it decreases in most cases over the life-span of a patent.

In this study the terms patents and patent families are used synonymously. Technically, the term "simple patent family" is correct. A simple patent family is a collection of patent documents that are considered to cover a single invention. The technical content covered by the applications is considered to be identical. Members of a simple patent family will all have exactly the same priorities[4].

More than one million active patent families have been analysed in this study just for the current year. This number is multiplied for each year going back to the year 2000. The included patents are based on the place of residence concept. If at least one researcher with an address in Switzerland is named on the patent, this patent will be included in the analysis. This also means that a patent that has been applied for in Switzerland by a Swiss company that lists researchers living in other countries will not be included.

2.3 Patent Counting

In this study the patents are identified and counted according to the reporting date concept – all active and published patent families and applications at a specific point in time are counted. This differs from other patent analyses where only new patent applications per year are counted. Whereas the latter concept focusses on the dynamics of patent development, the approach used in this study focusses on the absolute size and strength of a patent portfolio in a given year. For example, the reporting date 2017 (31. December) includes all granted patents and pending applications published up to this day. Still active patents from all previous years are included.

A patent is the fruit of research usually carried out by more than one researcher, often by more than one institution and sometimes more than one country. The question arises, how these patents should be counted and who they should be attributed to. The fundamental choice is between fractional counting, where a fraction of a patent is attributed to each of the contributors, and full counting, where a patent is attributed in full to each contributor.

An example might illustrate the advantage of full counting: a research institute which is well connected with the international research community might cooperate on many patents. This institution would have significantly less patents with fractional counting than an institution which is not connected. Full counting ensures that the

[4] The priority period starts with the first application to patent an invention in any country. Within the following 12 months the applicant is entitled to patent the same invention in other countries. However, the applicant can claim the priority date of the first application for these subsequent applications. This means that for these additional applications, this priority date will be respected in evaluating the novelty of the invention.

competencies of each institution is adequately reflected in patent numbers. A disadvantage of the full counting method is that it multiplies the number of patents by the number of institutions appearing on the patent publication as owners of the patent. In this report the full counting method is used to better reflect the work of the institutions.

It has to be noted that a university, research institution or company can only be identified as connected to a patent if it is named as (co-) owner on the patent. However, patenting strategy can differ quite substantially between research institutions and universities in different countries. For example, US universities generally patent inventions and license them to firms. While most Swiss research institutions and universities have followed this trend and have established technology transfer offices to manage and license patents, there is still a large diversity in patent strategies within and across countries. Consequently, universities with less systematic patent strategies might be underrepresented.

Apart from shared ownership, many patents share more than one technology. This is due to the fact that patents are generally categorized into several patent classes. The International Patent Classification (IPC) system currently consists of more than 70'000 classes. Technologies are usually defined by grouping relevant patent classes and in many cases, there will be an overlap of patent classes between technologies. This is sometimes necessary and sometimes intended. An example might illustrate this: one of the technologies defined in this report is image analysis. Many aspects and methods are included such as 2D and 3D image analysis or video analysis. If one looks at the application of image analysis, even more options come up such as chip design inspection, facial recognition, medical x-ray image analysis, or the real-time analysis of obstacles for autonomous vehicles. Facial recognition, for example, can also be regarded as an image analysis technology but also as a security technology replacing passwords to gain access to data, networks or even places. Therefore, there will be an overlap between image analysis technologies and security technologies. Because this report's main focus is on technology analysis using patents as the main tool, the overlap is intended. In addition, the full counting method is applied, as well.

Consequently, the sum of the number of patents per technology is greater than the number of patents associated with the ETH Domain.

1037 active and published patents were owned by the ETH Domain at the end of 2017. 671 of these patents were identified for the 17 technologies as active patents in the year 2017. The remaining 366 patents come from an extremely wide range of research areas making it impossible to group them into technologies which can be compared on a national and international level. However, two thirds of all patents were identified and associated with the 17 technologies.

910 patents result in the aggregation of the 17 technologies. This is due to intended overlaps between technologies and co-ownerships, as described above. This number is the relevant level of analysis for the report.

2.4 Identification and Categorisation of Major Swiss Research Institutions

For the national comparison, universities, university hospitals, research institutions of national importance according to art. 15 of the Federal Act on the Promotion of Research and Innovation (RIPA), and private companies were considered. As shown in Table 2-2, all the universities and university hospitals are grouped in the same category, as are the research institutions of national importance. In the table, only institutions with patents in at least 1 of the 17 defined technologies since the year 2000 are listed.

Tab. 2-2 Categorisation of major Swiss research institutions

Universities (including university hospitals)	Research institutions of national importance
University of Basel	Swiss Institute of Bioinformatics, Lausanne (SIB)
University of Berne	Institute of Oncology Research, Bellinzona (IOR)
University of Fribourg	Istituto di Ricerca in Biomedicina, Bellinzona (IRB)
University of Geneva	Schweizerisches Institut für Allergie- und Asthmaforschung, Davos (SIAF)
University of Lausanne	Swiss Vaccine Research Institute, Lausanne (SVRI)
University of Neuchatel	Schweizerisches Tropen- und Public Health-Institut, Basel (TPH)
University of Zurich	Centre suisse d'électronique et de microtechnique, Neuchâtel (CSEM)
University Hospital of Basel	Inspire AG
University Hospital of Berne	
University Hospital of Geneva	
Centre hospitalier universitaire vaudois	
University Hospital of Zurich	

Source: BAK Economics, IGE, PatentSight

Almost no patenting activity for universities of applied sciences (UAS) can be observed within the 17 defined technologies. This might possibly be due to the fact that they are more active in other technologies not covered in this study. Another more likely explanation it that universities of applied sciences do not necessarily own the patents produced in the framework of joint projects with industry. Therefore, no further analysis was carried out for the universities of applied sciences.

3 ETH Domain Patent Activities – National Comparison

In this chapter, the significance of the ETH Domain patent activities within selected technologies is illustrated and compared to the patenting activities of companies and other research institutions in Switzerland. Switzerland's patents in each of the 17 technologies are identified and assigned to either institutions or companies. The core question that will be answered is: How significant is the ETH Domain research activity in each technology compared to companies and other research institutions. The focus will be on a comparison of world class patents and total patents.

The analysis will begin with an overview of the patenting activities of the ETH Domain in the 17 technologies, followed by a comparison with other Swiss research institutions. This is followed by a detailed analysis of the patenting activities in each technology comparing the ETH Domain to the top companies in each field. The chapter closes with an analysis of the patent quality structure for the ETH Domain.

3.1 Profile of the Patenting Activities of the ETH Domain

As a first step all patents of the ETH Domain in the 17 technologies have been identified. In addition, the technologies have been clustered into several technology fields to produce a technology profile.

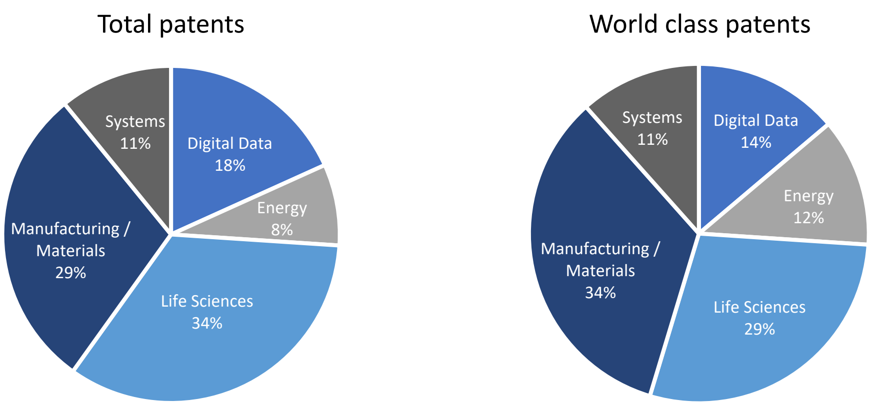
Tab. 3-1 Technology profile of the ETH Domain

Technology Field	Technology	Total Patents	World class patents	Patenting Efficiency
Digital / Data	Security Elements	63	17	27%
Digital / Data	Quantum Technologies	22	7	32%
Digital / Data	Digital Image Analysis	81	19	23%
Manufacturing / Materials	Advanced Materials	100	57	57%
Manufacturing / Materials	Nanostructures	132	48	36%
Manufacturing / Materials	Additive Manufacturing	34	0	0%
Systems	Mass Spectroscopy	59	12	20%
Systems	Drones	11	8	73%
Systems	Radiation Detectors	29	16	55%
Life Sciences	Biosensors, Lab-on-a-Chip. Bioprinting	53	16	30%
Life Sciences	Wearables Bionics	40	9	23%
Life Sciences	Radiation Diagnosis and Therapy	50	22	44%
Life Sciences	Protein Engineering	122	40	33%
Life Sciences	Drug Discovery Systems Biology	19	1	5%
Life Sciences	Classic Organic Pharmaceutically Act. Subs.	24	1	4%
Energy	Organic Perovskite Tandem Photovoltaics	43	24	56%
Energy	Waste Water, Biomass, Carbon Capture	28	14	50%
Total		**910**	**311**	**34%**

Source: BAK Economics, IGE, PatentSight

A total of 910 patents are covered in the defined technologies[5]. Patenting activities are not evenly spread across technologies, but this is mainly due to structural differences in technologies as some technologies are more patent intensive. Focussing on the technology fields, life sciences technologies and manufacturing / materials dominate in total patent counts. Although both technology fields also dominate the top rated world class patents, manufacturing / materials show a significantly higher share of world class patents compared to their share of total patents[6]. Conversely, Life Sciences shows a lower share of world class patents compared to their total share.

Chart 3-1 Structure of ETH Domain technology fields (total patents and world class patents, 2017)



Note: This chart only includes patents in the 17 technologies. The ETH Domain has 366 additional patents in other technologies which are not covered here.
Source: BAK Economics, IGE, PatentSight

[5] Double countings are possible because a patent can be assigned to more than one technology or to more than one institution. The actual patent base is 671. Two thirds of all ETH patents are covered in the 17 technologies.
[6] Most world class patents can be found in materials. Manufacturing (additive manufacturing) has a very low number of world class patents for statistical reasons explained in the following chapters.

3.2 ETH Domain Compared to other Swiss Research Institutions

The following chart shows the patent activities of the other institutions compared to the ETH Domain. World class patents and total patents (in parenthesis) are shown.

Tab. 3-2 Patent overview for major Swiss research institutions, world class patents and total patents, 2017

Technology	ETH Domain	Universities	Research institutions of national importance
Security Elements	17 (63)	2 (3)	4 (11)
Quantum Technologies	7 (22)	1 (9)	1 (3)
Digital Image Analysis	19 (81)	4 (20)	0 (2)
Advanced Materials	57 (100)	2 (9)	1 (8)
Nanostructures	48 (132)	13 (31)	4 (18)
Additive Manufacturing	0 (34)	4 (9)	0 (1)
Mass Spectroscopy	12 (59)	2 (40)	0 (0)
Drones	8 (11)	0 (0)	0 (0)
Radiation Detectors	16 (29)	0 (6)	0 (5)
Biosensors, Lab-on-a-Chip. Bioprinting	16 (53)	4 (12)	1 (10)
Wearables Bionics	9 (40)	1 (4)	0 (9)
Radiation Diagnosis and Therapy	22 (50)	15 (48)	2 (4)
Protein Engineering	40 (122)	53 (196)	12 (24)
Drug Discovery Systems Biology	1 (19)	6 (11)	1 (2)
Classic Organic Pharmaceutically Act. Subs.	1 (24)	2 (31)	0 (1)
Organic Perovskite Tandem Photovoltaics	24 (43)	0 (3)	1 (1)
Waste Water, Biomass, Carbon Capture	14 (28)	0 (0)	0 (0)

Source: BAK Economics, IGE, PatentSight

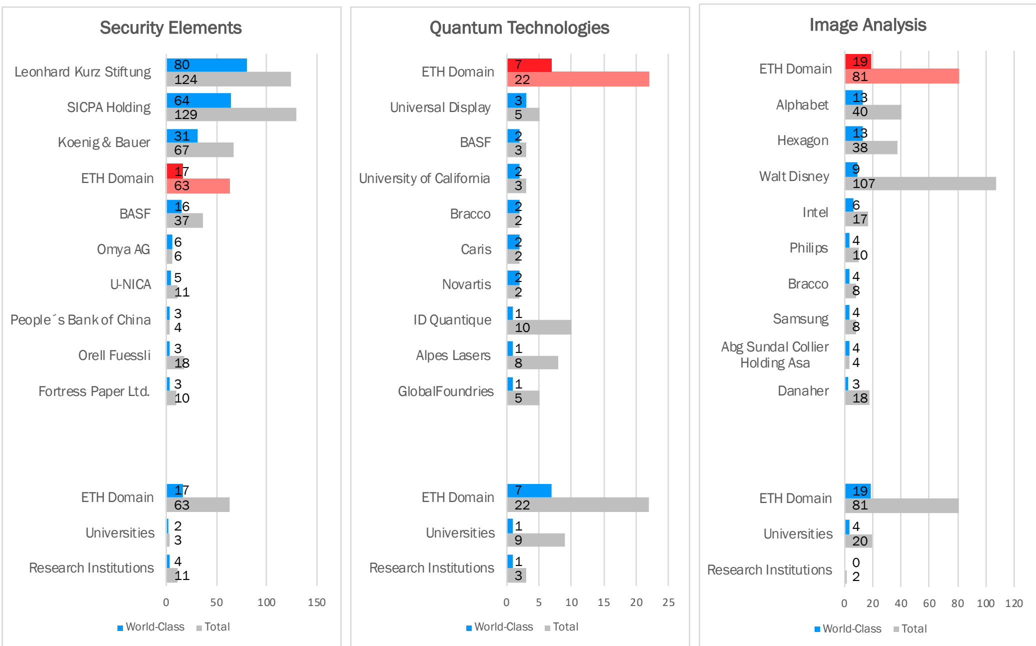
The universities are active in most technologies but show clear focus areas in protein engineering, radiation diagnosis and therapy, and mass spectroscopy. Two thirds of their patents in the 17 technologies belong into these three categories.

3.3 Comparison of the Research Activities of ETH Domain with Top Companies

This chapter provides a detailed analysis of the patenting activities in each technology comparing the ETH Domain to the top Swiss companies in each field. On each chart the companies and institutions are ranked according to the number of world class patents they own. The top bar shows world class patents and the bottom bar shows total patents for each institution or company. If several companies have the same number of patents, they are shown in alphabetical order. The ETH Domain is highlighted in red to facilitate reading. For informational purposes, the patents for the Swiss research facilities and universities are shown at the bottom of each chart. Longer lists with patent information for up to 40 companies for each technology can be found in the annex to this study.

Foreign entities appear in this ranking due to the fact that a patent might be generated in Switzerland but as part of an international collaboration which it is then attributed to. Likewise a patent application conceived and reduced to practice in CH might be filed at a point in time where a researchers affiliation has changed.

Chart 3-2 Digital / Data technologies: Comparison of ETH Domain with top companies, total patents and world class patents, 2017



Source: BAK Economics, IGE, PatentSight

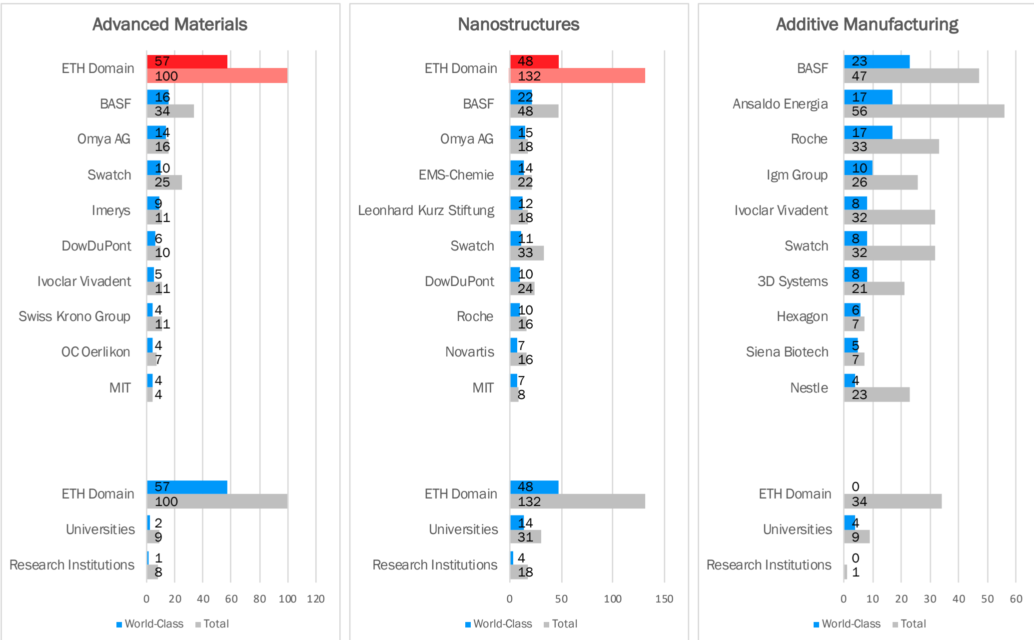
The chart above shows the top companies in Switzerland in the three defined digital / data technologies in total patents and world class patents compared to the ETH Domain. Sorted by number of world class patents, the ETH Domain takes the top spot in quantum technologies as well as in image analysis technologies and is in fourth place in security elements. For illustration purposes the ETH Domain, the Swiss universities, and research institutions of national importance are also listed at the bottom of each graph.

Security elements covers a wide range of security aspects from product safety to internet-technologies. The leading companies have a focus on banknotes, security printing colors and security foil for passports and other official documents. The ETH Domain is active in a wide range of subjects from safety features for product packaging to blockchain-technologies and is ranked fourth behind the specialized security printing companies. The ETH Domain owns one of the few highest-rated blockchain patents worldwide.

Quantum technologies is still in a very early stage of development and consequently most research is considered fundamental research and takes place completely in research institutions and universities. It is therefore not surprising that overall research activity is considerably lower than in the other more applied research-oriented fields and that the ETH Domain takes the top-spot in this technology by a wide margin. Other universities in Switzerland are also active in this field, most importantly the University of Geneva. It has to be noted that the ID Quantique is a spin-off from the University of Geneva and its patents stem from joint research projects with the university and are co-owned.

Image analysis is a technology where the ETH Domain takes the top-spot with 19 world class patents. This technology covers both two-dimensional and three-dimensional image analysis. Many patents have been developed in close cooperation with Disney and are co-owned. In this case the ETH Domain research relates to computer-generated films, but image analysis can be applied in various other forms such as facial recognition.

Chart 3-3 Manufacturing / Materials: Comparison of ETH Domain with top companies, total patents and world class patents, 2017

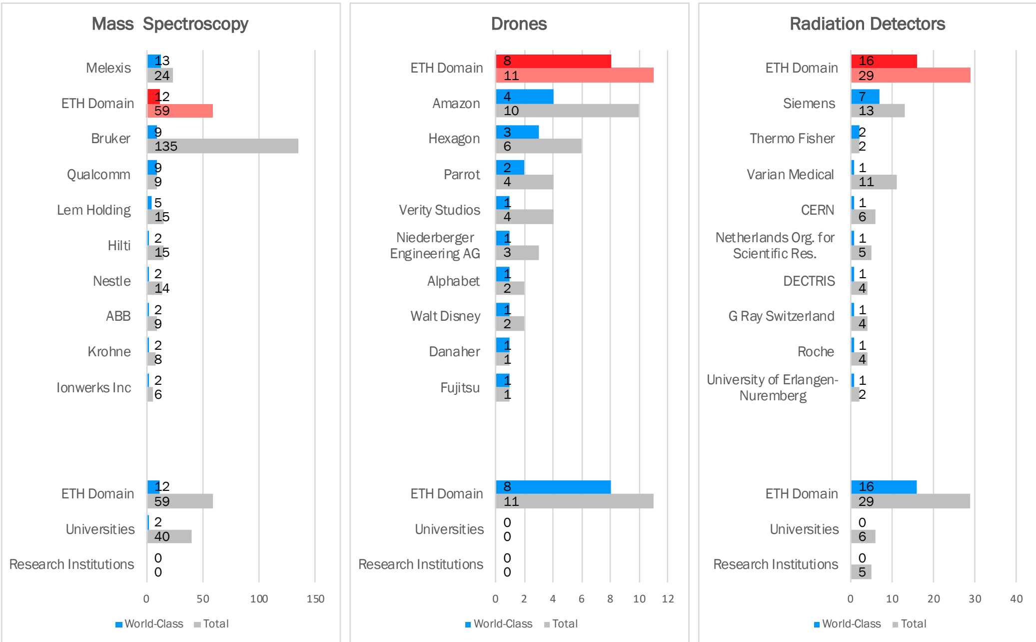


Source: BAK Economics, IGE, PatentSight

The ETH Domain is leading the advanced materials and nanostructures technologies in Switzerland by a wide margin. Advanced materials is a traditional strength of many institutions of the ETH Domain. In nanostructures IBM would be in second place from the perspective of total patent count (70) but does not make the top 10 due to the lower number of world class patents.

Additive Manufacturing is a new technology field and can be approached from different perspectives. BASF, for example, focusse on 3D-printing materials to extend the range of possible applications. Roche is active in medical applications ranging from organ printing to individually produced prostheses. The ETH Domain ranks in third place in total patents but is not listed among the leading companies in this field due to the low number of world class patents. However, seven patents from the ETH Domain just missed the world class top 10% decile by a decimal place and are sorted into the 9th decile[7].

Chart 3-4 Systems: Comparison of ETH Domain with top companies, total patents and world class patents, 2017



Source: BAK Economics, IGE, PatentSight

The ETH Domain is well positioned in the three systems technologies mass spectrometers, drones and radiation detectors. The three technologies are ideally suited for ETH Domain research due to their wide range of applications.

The ETH Domain ranks in second place in mass spectrometers, a technology that allows the analysis of the composition and origin of a material by quantifying its atoms and molecules. Mass spectrometry is used in many different applications in biology, chemistry, physics and clinical research. This also explains the significant activities of the other Swiss universities with 40 patents.

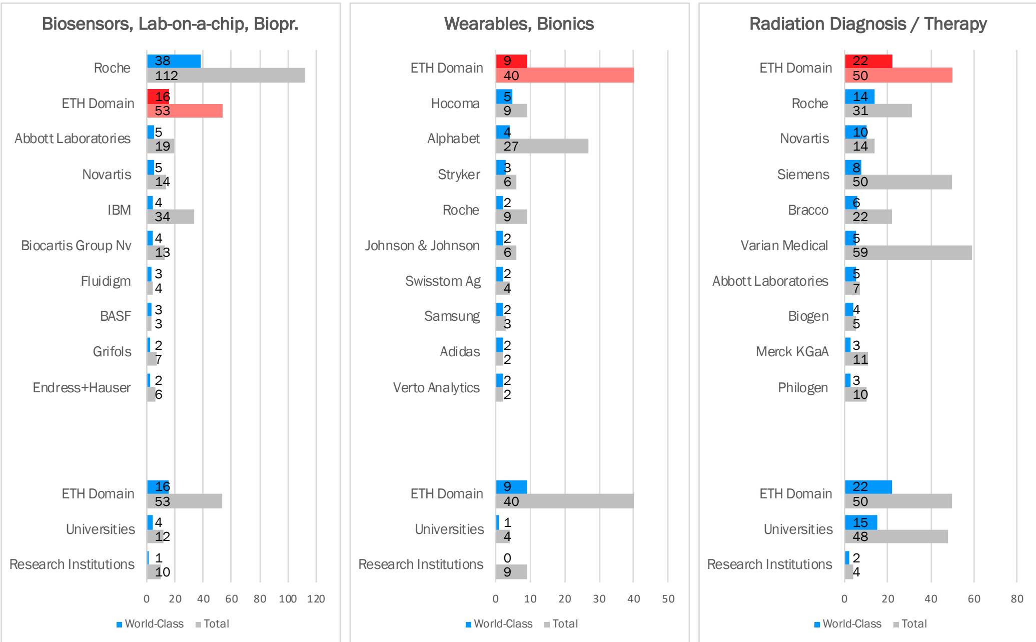
The ETH Domain is leading the research in drones with a large share of world class patents in a rather young technology. Drones and their various forms and purpose require fundamental research from different perspectives. This explains the activities from companies like Amazon which are interested in drone applications in logistics. Alphabet's activities overlap with their research in autonomous vehicles. The ETH Domain covers the fundamental aspects of the technology from various angles.

Radiation detectors are widely used within the nuclear, medical and environmental fields. This explains the activities of Siemens and Roche in this field. However, the

[7] In the case of additive manufacturing the top decile starts with values of 5.3 and above. 7 ETH-Patents have values of 5.2. Furthermore, 54% of all ETH Domain patents in this technology are in the 9th decile. In comparison, the values for IBMs nanostructures patents are more evenly distributed among the deciles. A slightly more flexible application of the 10% rule for world class patents would not increase IBMs world class patents in this technology. Please refer to the methodology at the beginning of the study for more information on quality calculations and deciles of patents.

most advanced radiation detectors are being used at the CERN in Geneva. The ETH Domain activities originated in CERN projects but have since diversified significantly.

Chart 3-5 Life Sciences (I): Comparison of ETH Domain with top companies, total patents and world class patents, 2017



Source: BAK Economics, IGE, PatentSight

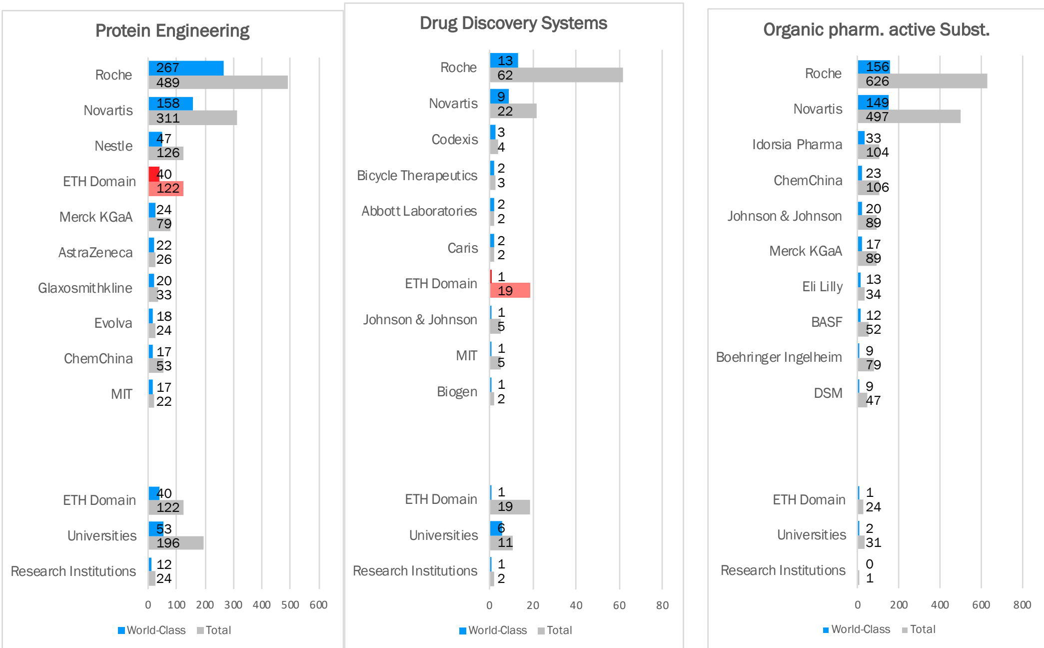
Life Sciences are obvious technology fields for the ETH Domain with such a large life science industry in near proximity. On the one hand intensive competitiveness should lead to better results and possible joint projects, however on the other hand massive research and development activities by the life science industry forces the ETH Domain to carve out niches in new and growing technologies.

The technologies of biosensors, lab on a chip and bioprinting fit the definition of new and growing technologies. All three are expected to have a large impact on the life sciences sector – biosensors to detect and diagnose diseases, bioprinting with high expectations for tissue creation and lab-on-a-chip technologies for new forms of diagnostics. The ETH Domain is well positioned with almost 53 patents of which 16 can be considered world class.

Wearables and Bionics are technologies ranging from electronics worn on the body to wearable exoskeletons. Both technologies focus on enhancing or replacing body functions. The ETH Domain leads the research field in Switzerland by a wide margin. Alphabet/Google is also active in this field in Switzerland with their research in glasses with additional functionality. The universities in Switzerland are also active in this field.

Radiation therapy utilizes medical imaging technologies in the diagnostic evaluation of patients. Many players are active in this field, mostly from the life sciences industry. The ETH Domain leads the field with most world class patents but also with a very high research efficiency (share of world class patents to total patents). The universities and especially the university hospitals play a major role in this field.

Chart 3-6 Life Sciences (II): Comparison of ETH Domain with top companies, total patents and world class patents, 2017



Source: BAK Economics, IGE, PatentSight

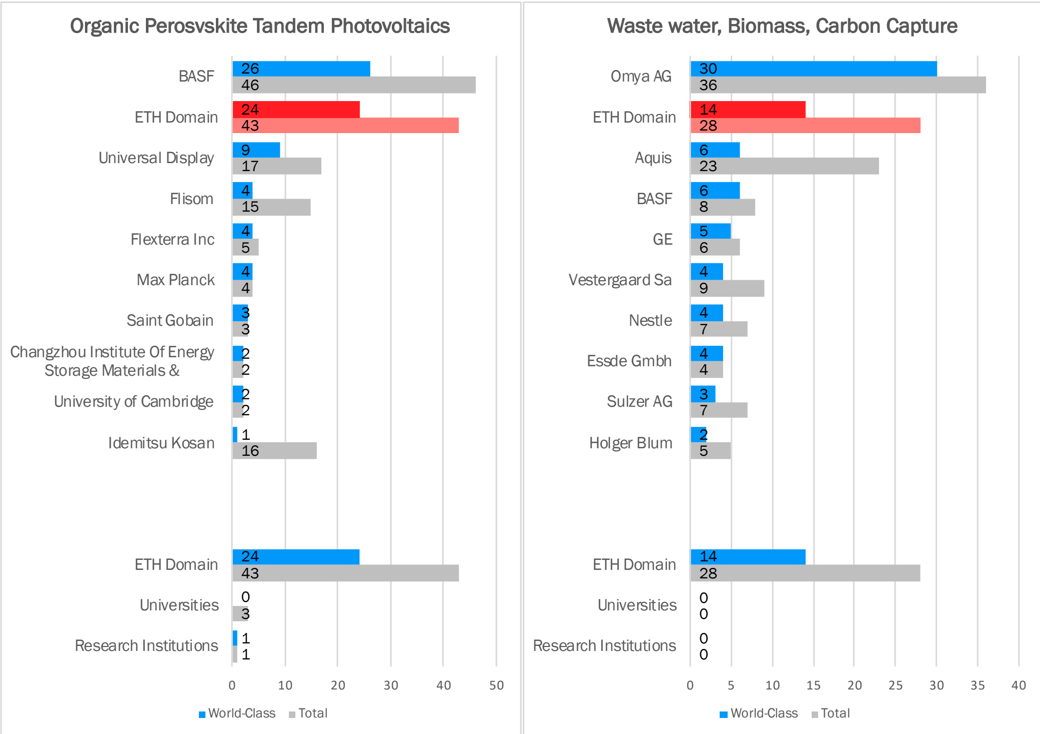
The second set of life science technologies shows the above-mentioned effect of intense activities of the life science industry. The big Swiss pharmaceutical companies are ranked in the top places in Protein engineering, drug discovery systems and organic pharmaceutically active substances.

Protein engineering plays a central part in creating smart, stimulus-responsive drugs by developing proteins with desired properties. Roche and Novartis lead the field especially in terms of world class patents and research efficiency. The ETH Domain comes in fourth place with 35% of its patents as world class. Furthermore, the Swiss universities play a major role as well in this technology field and are slightly ahead of the ETH Domain both in terms of total patents and in world class patents.

In Drug discovery systems, the ETH Domain would be in third place in terms of total patents but ranks much lower because of only one world class patent. In contrast to the additive manufacturing technology above, the other patents are quite evenly distributed among the deciles. The Swiss universities would rank above the ETH Domain due their world class patents.

Organic pharmaceutically active substances is a technology that is clearly dominated by the major Swiss pharma companies. Combined, Roche and Novartis hold more than 1000 patents with more than 300 of world class quality. The ETH Domain and also the Swiss universities only show reduced activities in this field with 24 patents of which only one reaches world class status.

Chart 3-7 Energy: Comparison of ETH Domain with top companies, total patents and world class patents, 2017



Source: BAK Economics, IGE, PatentSight

Energy technology and especially the search for new and optimized solutions in renewable energy systems is a typical area of expertise for research institutions. Consequently, the ETH Domain ranks high in these technologies.

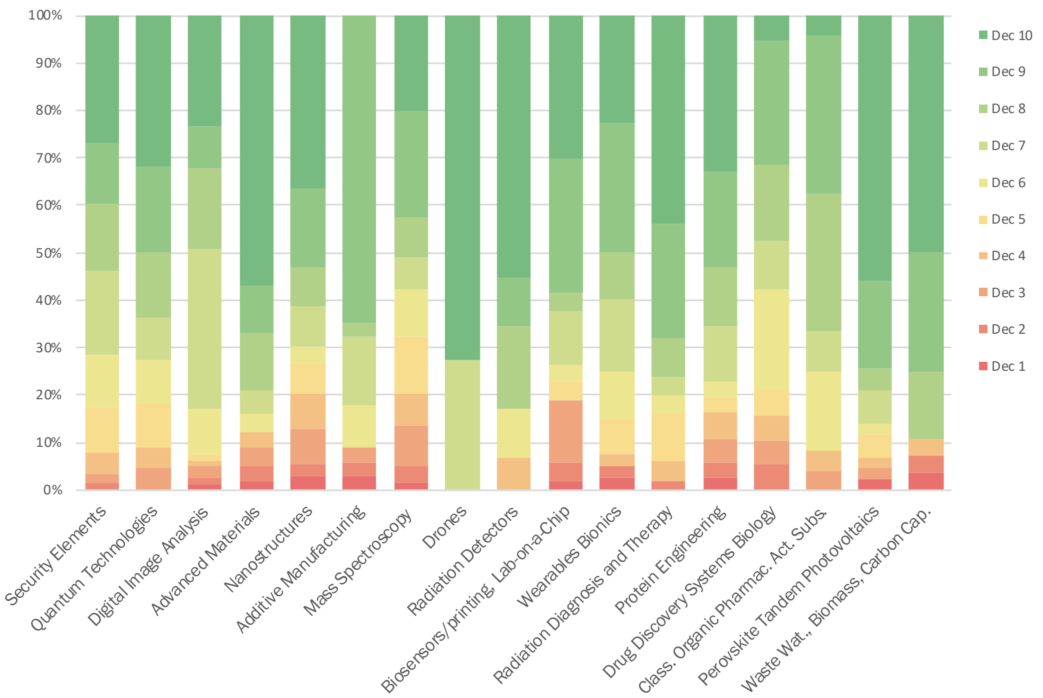
Perovskite and organic photovoltaic cells are particularly promising areas of solar power research. However, further research is necessary before perovskite and organic solar cells are able to compete with silicon-based cells on the commercial solar power market. This explains the dominance of the research institutions in this field in Switzerland. The ETH Domain is only surpassed by BASF as the leading company in this field. Furthermore, the lack of world class patents hides the fact that more than 120 active patents can be counted from smaller players in the field. Nevertheless, the technology cluster clearly consists of just a few major players including the ETH Domain.

Waste water, Biomass and carbon capture are a combination of three technologies that play an important role regarding sustainable development. Technically this group consists of three different technologies which explains the wide range of companies active in these fields. However, Omya is active in carbon capture and water treatment and ranks highest with 30 world class patents. The ETH Domain comes second with 14 world class patents from all three technologies.

3.4 Quality Structure of ETH Domain Patents

The previous chapter compared top rated patents and total patents between the ETH Domain and companies. In some cases, the focus on world class patents concealed the fact that the ETH Domain patent portfolio in general is of above average quality. In this short section, the patent quality structure in deciles for the ETH Domain is shown for each technology.

Chart 3-8 Patent structure of the ETH Domain by technology and quality, 2017



Source: BAK Economics, IGE, PatentSight

Structuring the patent portfolio into deciles, from the top-10% to the bottom-10%, it can be shown that the patent structure of the ETH Domain in each technology is of above average quality. In 12 technologies 50% of the patents are of very high quality and in the case of the energy technologies, drones and radiation detectors, the top 2 deciles account for more than 70% of the patents. Furthermore, only very few patents can be found in the low-quality deciles. This clearly demonstrates the above average quality of the ETH Domain patent portfolio.

3.5 Additional Direct and Indirect Patent Activities associated with the ETH Domain

The previous chapters have focused on the number and quality of patents owned or co-owned by the ETH Domain. However, not all research activities within the ETH Domain result in patents owned by the ETH Domain. In some cases, patents are solely applied for by cooperating companies or institutions. It is therefore more than likely that more research activities and more patents can be associated with the ETH Domain than were identified up to this point.

To gain further insights, additional patent data has been analysed focusing on information about the owner(s) of the patent, the inventor(s) and citations of other relevant patents.

Joint research projects –cooperations between the ETH Domain and industry

A substantial part of the research is carried out in the form of national or international research cooperations involving other institutions, universities or companies. In most cases these cooperations are of general nature and result in a new state of the art, in some cases, the joint research projects result in patents which are jointly owned by the involved institutions and companies. ETH Domain projects with 181 partners have led to 376 currently active co-owned patents. These co-owned patents were taken into account in the national and international comparison in the previous chapter. Since many patents stem from long-standing cooperations the total number of owners is lower than the total number of patents.

More precisely, 125 companies have cooperated with the ETH Domain leading to 243 patents. Cooperations with 56 national or international research institutes or universities have produced 133 patents. The institutions of the ETH Domain each have set up industry relation or technology transfer offices to support these cooperations.

Furthermore, the ETH Domain licenses the use of its patents to companies. Whereas licensing and co-ownership relate to patents already identified and (co-) owned by the ETH Domain, in some cases the resulting patents from joint research projects are solely owned by the partner, based on contractual agreements. Information from the ETH Domain institutions suggests that 479 patents solely owned by companies or other research institutions stem from joint research projects with the ETH Domain.

Patent citations – ETH Domain patents referred to by third parties

Apart from direct research cooperations, companies and research institutions are also interested in patents owned by the ETH Domain. Published patent documents usually include a list of references that were cited either by the examiner of the patent office to evaluate patentability or by the applicant to show the novelty of the research. Analysis of the citations shows that ETH Domain patents in the 17 selected technologies have been cited in 5041 third party patents by 393 universities and research institutions and 1552 companies.

Inventors with an ETH Domain background

So far it has been shown that a significant number of companies is actively involved in direct research cooperation with the ETH Domain, and an even larger number is interested in ETH Domain patents themselves. In addition there is also interest in the inventors – the researchers named on the patent.

In total 3620 inventors are named on currently active ETH Domain patents in the 17 defined technologies. However, it can be assumed that these inventors have been named on additional patents not owned by the ETH Domain for the reasons explained above. A corresponding analysis[8] that widens the scope to all patents that can be attributed to these inventors regardless of ownership of the patent returns 3801 additional patents in Switzerland. This means that inventors who have been named on ETH Domain patents while working for the ETH Domain have also been named on 3801 additional patents owned exclusively by companies, after they have left the ETH Domain and went on to do industry research in Switzerland[9].

3.6 Conclusion

In conclusion it can be observed that the ETH Domain is in the top position in a wide range of technologies such as quantum technology, image analysis, advanced materials, nanostructures, drones, radiation detectors, wearables and perovskite photovoltaics. The ETH Domain ranks in first place in 8 out of 17 technologies and in the top five in six additional technologies.

The patent structure of the ETH Domain in each technology is of above average quality. In 12 technologies 50% of the patents are of very high quality and in the case of the energy technologies, drones and radiation detectors, the top 2 deciles account for more than 70% of the patents. Furthermore, only very few patents can be found in the low-quality deciles.

The ETH Domain is very active in joint research projects with industry or other research institutions. 376 co-owned patents stem from joint research projects. The ETH Domain participated in joint research for an additional 479 patents which are solely owned by the partnering company or institution. Furthermore, ETH inventions are highly relevant. 1945 companies and research institutions worldwide cite ETH Domain inventions in 5041 third party patents. Former ETH Domain inventors remain very active once they go on to do industry research in Switzerland. 3801 company patents list at least one inventor who has worked and patented for the ETH Domain before joining the respective company.

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[8] It is important to note that the analysis identifies names not persons. Especially with common names like “Müller”, “Smith”, “Patel” or “Ming”, the risk of matching several names with one person increases. For example, a simple world-wide search for patents returns more than 150’000 active patents with at least one of the identified names listed as inventors. To narrow down the results and to reduce the error probability, the search is applied to persons with an address in Switzerland. It is assumed that most inventors leaving the ETH Domain to work for industry remain in Switzerland. As this study focusses on the effects of the ETH Domain on Switzerland such a local containment is reasonable.

[9] The analysis is based on inventors who have been named on a patent while working for the ETH Domain. Researchers who started patenting after leaving the ETH Domain cannot be identified with this approach. Also, it only focusses on the 17 technologies identified for this study. Patent activities in other technologies are not identified with this approach.

4 ETH Domain Patent Activities – International Comparison

In this chapter the ETH Domain will be compared to some of the most renowned universities and research institutions worldwide. Four institutions from the USA (MIT, Harvard, Stanford and the University of California), three institutions and universities from Europe (CNRS, Fraunhofer and the University of Oxford) and three institutions and universities from Asia (Chinese Academy of Sciences, Tsinghua University and the Japan Science and Technology Agency) were chosen for the analysis. It has to be noted that the institutions are of different size in terms of numbers of staff, researchers or budget. Also, some are pure research institutions, others offer research and teaching. Some are purely publicly funded, and some receive funding from mixed sources (private and public). These differences make it difficult to apply statistical normalisation procedures to correct for the very different sizes of the compared institutions.

4.1 Total Patents – a Short Overview

This analysis is done for world class patents, only. As described in the methodology, patent analyses based on total patent counts generally lead to unsatisfactory results because distorting effects due to country-specific differences in the patenting systems. For example, traditionally in Japan intellectual property is patented much earlier than in other countries. In China, researchers are incentivized to patent as much as possible in order to increase the relevance of China as a research location. The simple measurement of patent activity in terms of new registrations exaggerates the importance of certain countries and distorts the overall picture.

An example might illustrate this point. The table below shows the 10 international research institutions that will be analysed and compared to the ETH Domain in this chapter. These institutions own a total of almost 42’000 patents in the 17 selected technologies. The Chinese Academy of Sciences alone owns 19’000 of these patents and distorts the analysis due to the political pressure behind the Chinese patent activities.

Tab. 4-1 Patent overview for 10 international research institutions and the ETH Domain, world class patents and total patents, 2017

Institution	Total patents	World class patents	Patenting efficiency
Chinese Academy of Sciences	19'124	441	2%
University of California System	5'164	949	18%
Tsinghua University	4'968	531	11%
CNRS	2'925	319	11%
MIT	2'308	868	38%
Fraunhofer	1'820	184	10%
Stanford University	1'728	255	15%
Harvard	1'563	807	52%
Japan Science and Technology Agency	1'158	110	9%
ETH Domain	910	311	34%
University of Oxford	431	142	33%

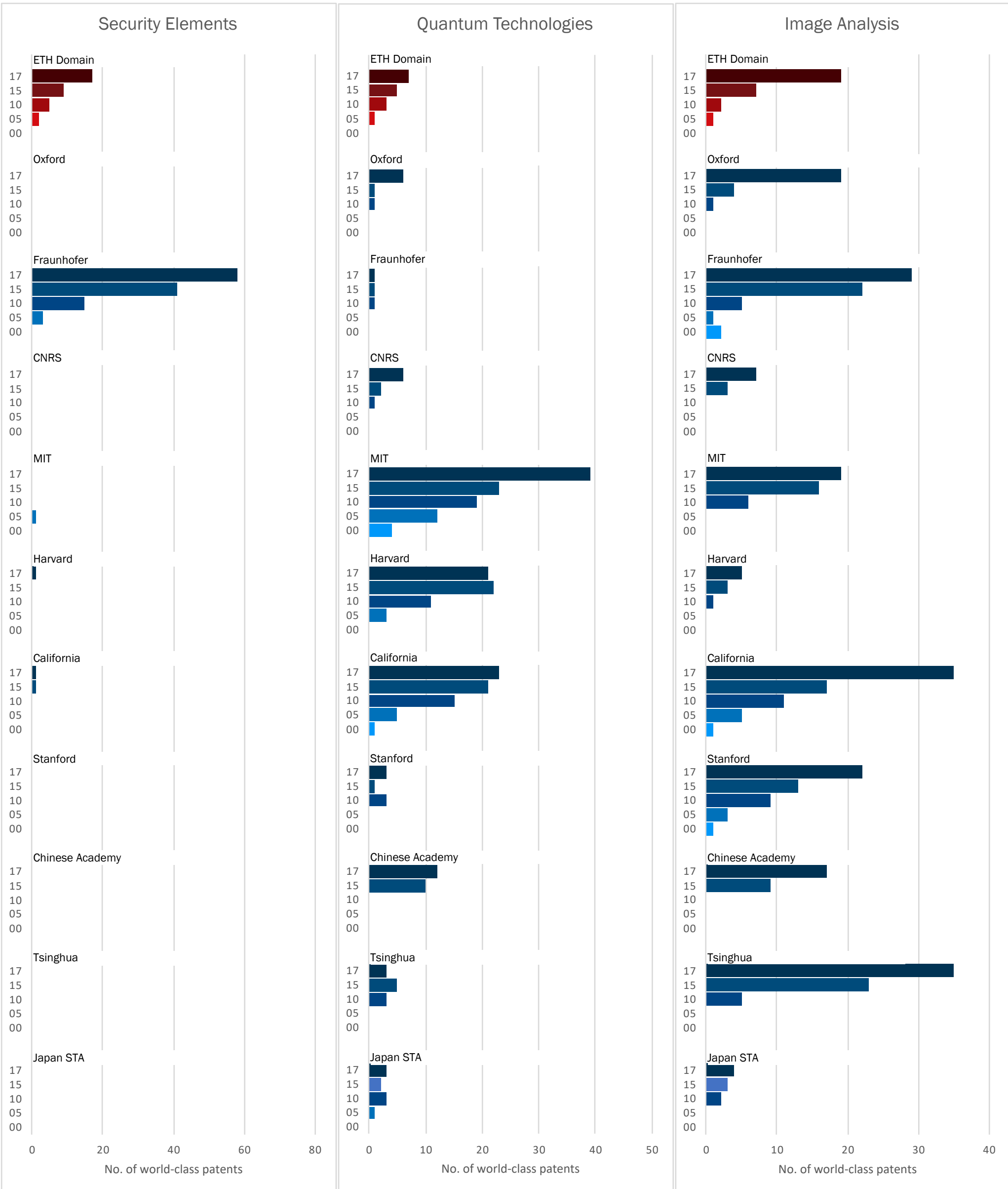
Source: BAK Economics, IGE, PatentSight

The table above also provides some valuable first insights. Although total patenting differs quite substantially between the institutions, they are comparatively close in terms of world class patents. Consequently, the patenting efficiency (share of world class patents in total patents) varies among the institutions. The ETH Domain has the third-highest patenting efficiency behind Harvard and MIT.

4.2 World Class Patents – a Detailed Analysis

The following international comparison shows the structure and development for the ETH Domain (top) and the international institutions. Five years are shown for each institution (2000, 2005, 2010, 2015, 2017). Complete time series for the years 2000-2017 can be found in the annex to this study.

Chart 4-1 Digital / Data technologies: Comparison of ETH Domain with international research institutions, world class patents, 2000-2017



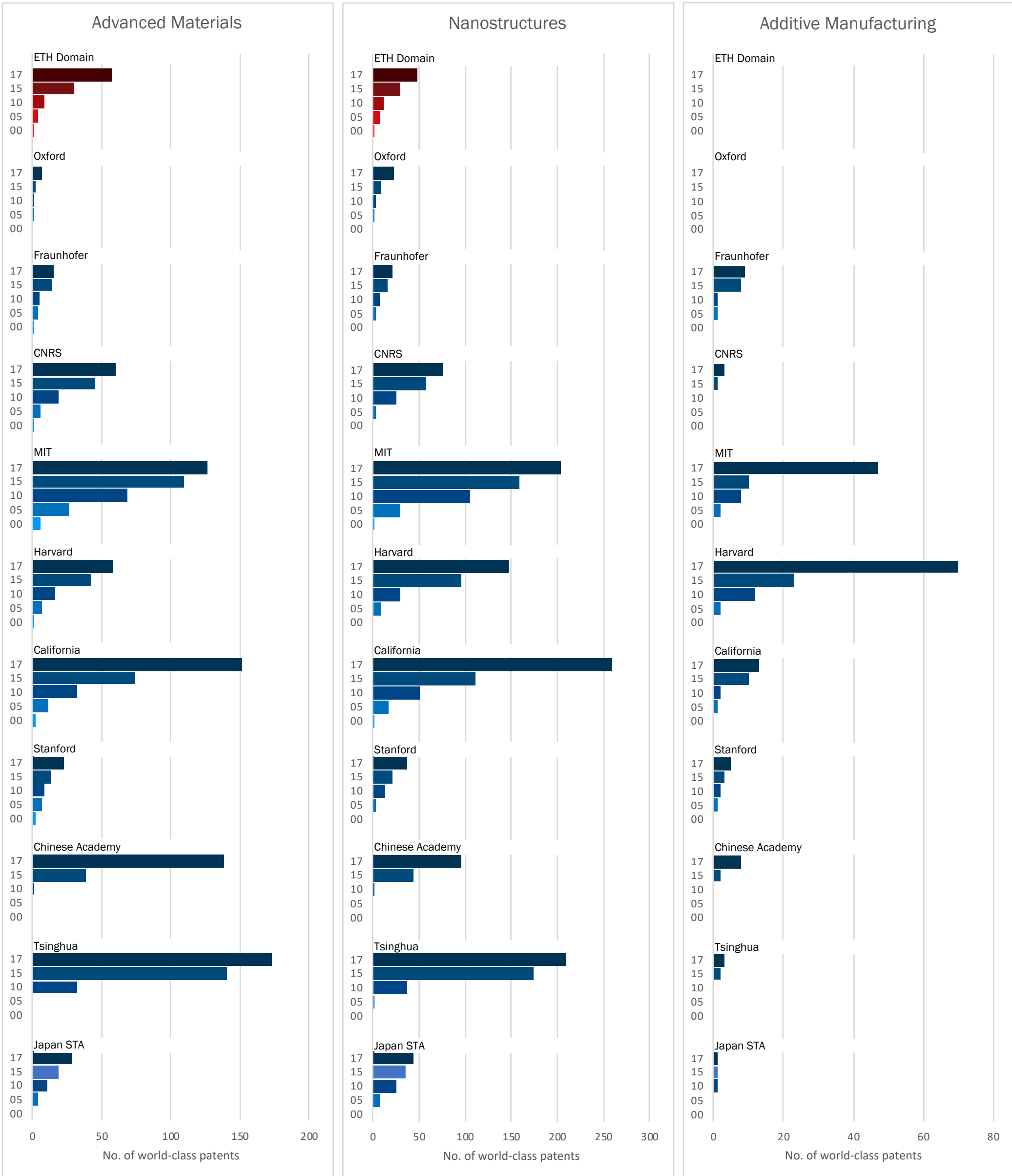
Source: BAK Economics, IGE, PatentSight

Security elements is an exclusive research domain for Fraunhofer and the ETH Domain. World class activities in other countries are nonexistent. It seems to be the case that the ETH Domain faces more national than international competition. In this technology area, the ETH Domain is second to Fraunhofer which sports a world class patent portfolio three times the size and also a higher growth rate.

In quantum technologies the ETH Domain is the leading research institution in Europe, but this technology is clearly a domain of the US-Universities with MIT leading with almost 40 world class patents in 2017 and also very reliable growth rates. While the developments are inconclusive at the Japan Science and Technology Agency and at the Tsinghua University, the Chinese Academy of Sciences managed to surpass the European institutions within just a few years.

Image analysis is an area of activity for all research institutions covered. Strong dynamics can be observed from the US-Universities, most notably MIT, and also from the Chinese institutions. Within Europe, the ETH Domain is second to Fraunhofer and can also keep up with the competition from Asia and the US.

Chart 4-2 Manufacturing / Materials: Comparison of ETH Domain with international research institutions, world class patents, 2000-2017



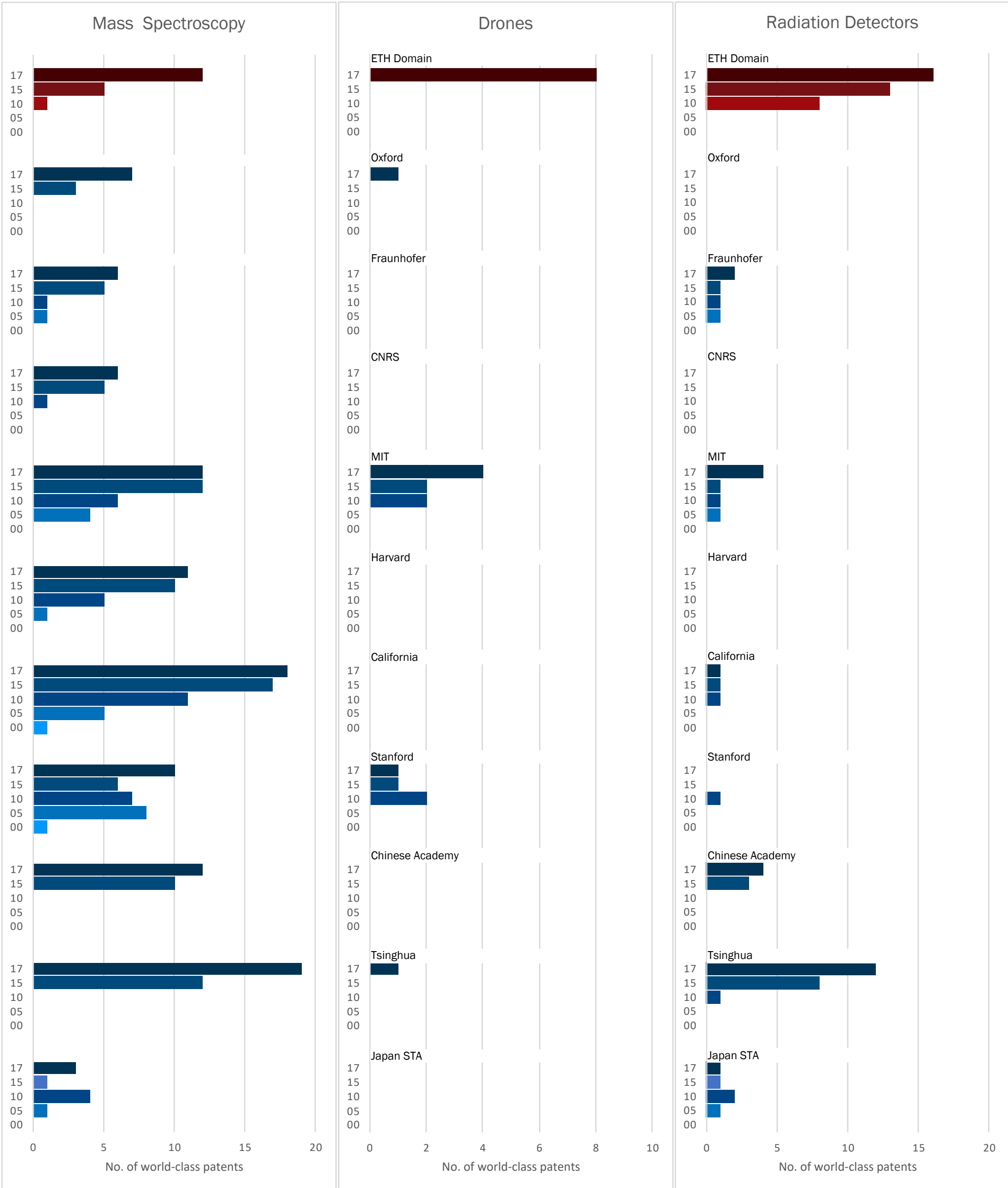
Source: BAK Economics, IGE, PatentSight

Advanced materials is one of the technologies where the Chinese institutions overtook the US-institutions within less than a decade. Massive growth rates put the University of Tsinghua in first place. The Chinese Academy of Science is also growing rapidly. Only the University of California System can keep up. The other institutions from the US and Europe are far behind and also lack the required pace to keep up. The ETH Domain shows a very positive development in recent years, especially compared to the rest of Europe.

Nanostructures shows a similar development as seen in advanced materials. There are, however, some subtle differences. Harvard together with the University of California and MIT manage to keep up with the University of Tsinghua and the growth rates of California seem to indicate that the picture from the field of advanced materials will not be repeated here. The ETH Domain is in a solid position but has not been able to differentiate itself from the other European institutions which are clearly behind the US.

Additive manufacturing is dominated by the MIT and Harvard. The other institutions are far behind. As mentioned in the national comparison, the ETH Domain has several patents that did not qualify for the world class definition but are not far behind. Even if one counts these patents as world class it would still not be sufficient.

Chart 4-3 Systems: Comparison of ETH Domain with international research institutions, world class patents, 2000-2017



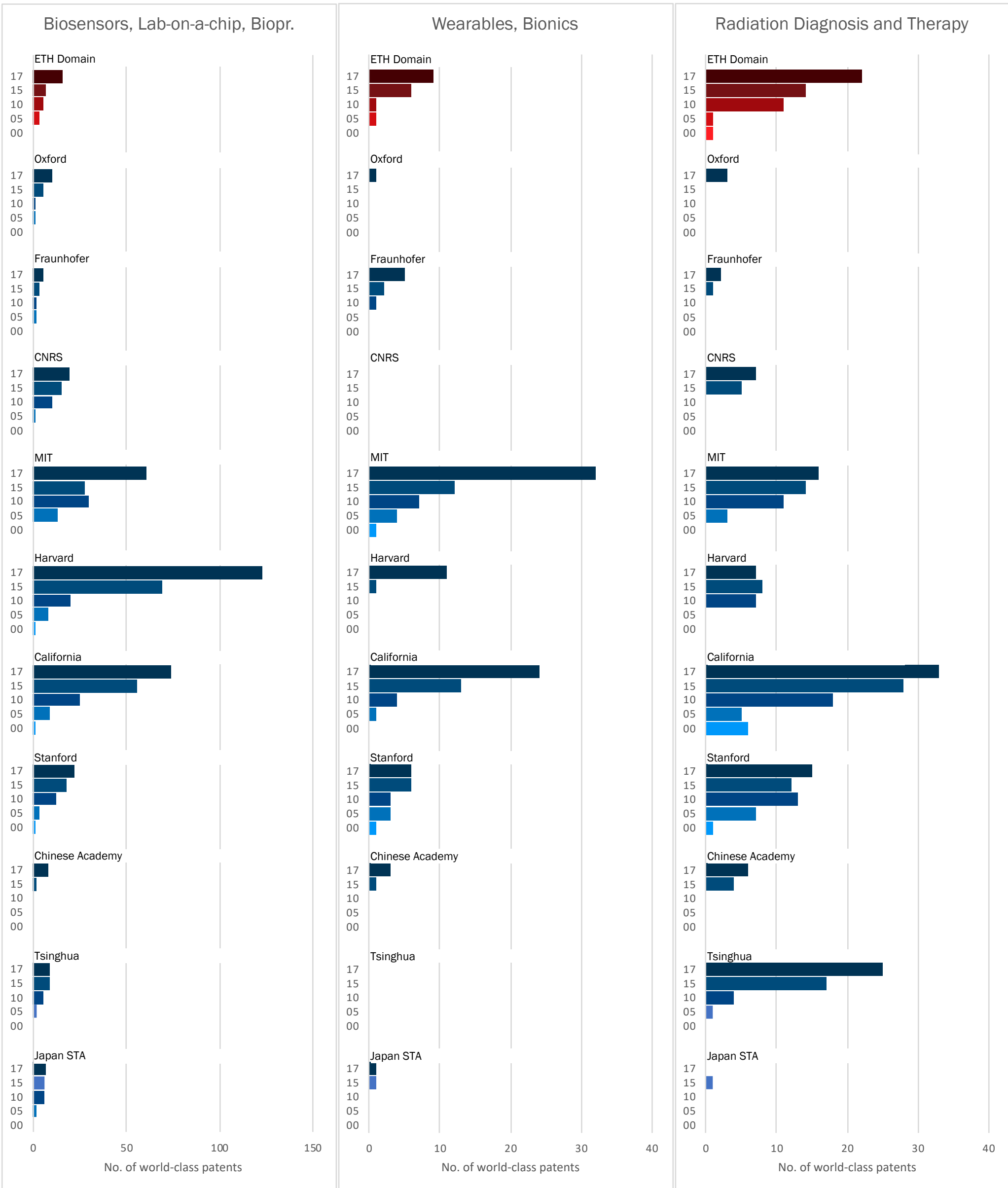
Source: BAK Economics, IGE, PatentSight

The ETH Domain has clear advantages in the field of systems technologies. It is leading research activities in mass spectroscopy together with Tsinghua University and the University of California. Due to rather low patent numbers in general, the development of all observed institutions seems erratic, but this is expected to disappear with more patent growth.

Drones is another special research area of the ETH Domain. The total number of world class patents still rather low compared to other technologies, but the ETH Domain is clearly ahead of the other institutions and demonstrates the highest growth rate. Only MIT seems to be in a position to keep up the pace in this area.

A similar situation can be observed for radiation detectors. Again, the ETH Domain takes the lead with 16 world class patents and growth rates hint at a continuation of this development for the coming years. Here, Tsinghua University manages to produce similar growth rates, but the US-institutions are far behind. In 2017 the ETH Domain had more world class patents than the European and US-institutions combined.

Chart 4-4 Life Sciences (I): Comparison of ETH Domain with international research institutions, world class patents, 2000-2017



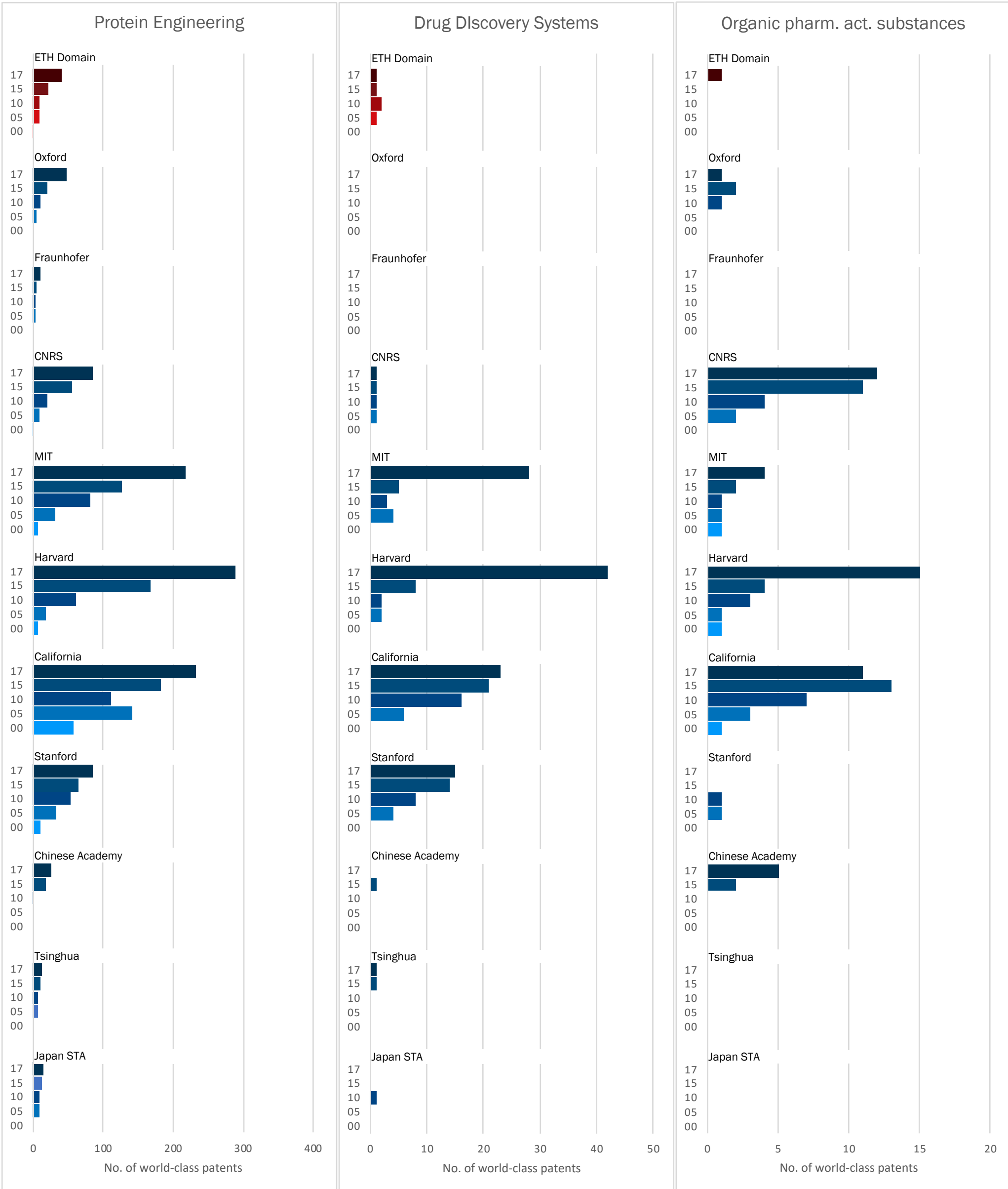
Source: BAK Economics, IGE, PatentSight

Biosensors, lab-on-a-chip and Bioprinting are clearly the domain of US institutions. On the national level the ETH Domain came in second only to Roche, however the international comparison clearly shows the leadership of the US institutions within these fields.

Wearables and bionics are again fields led by MIT and the University of California with both showing massive growth rates, especially in recent years. The ETH Domain also sports solid growth rates and finds itself in the middle of the field with regards to its technology development. It will not be enough to keep up with the US institutions but is enough to stay ahead of the European institutions.

Radiation diagnosis and therapy shows many different developments. The most important insight is that apart from the Tsinghua University, California and the ETH Domain, no real growth can be observed. In the national analysis the strong competition from other life sciences companies and also from the universities and probably the university hospitals could be seen. There might also be a similar development in other countries which hinders the institutions in question to differentiate themselves. However, it has to be noted that the ETH Domain comes in third place within distance of the Tsinghua University in second place.

Chart 4-5 Life Sciences (II): Comparison of ETH Domain with international research institutions, world class patents, 2000-2017



Source: BAK Economics, IGE, PatentSight

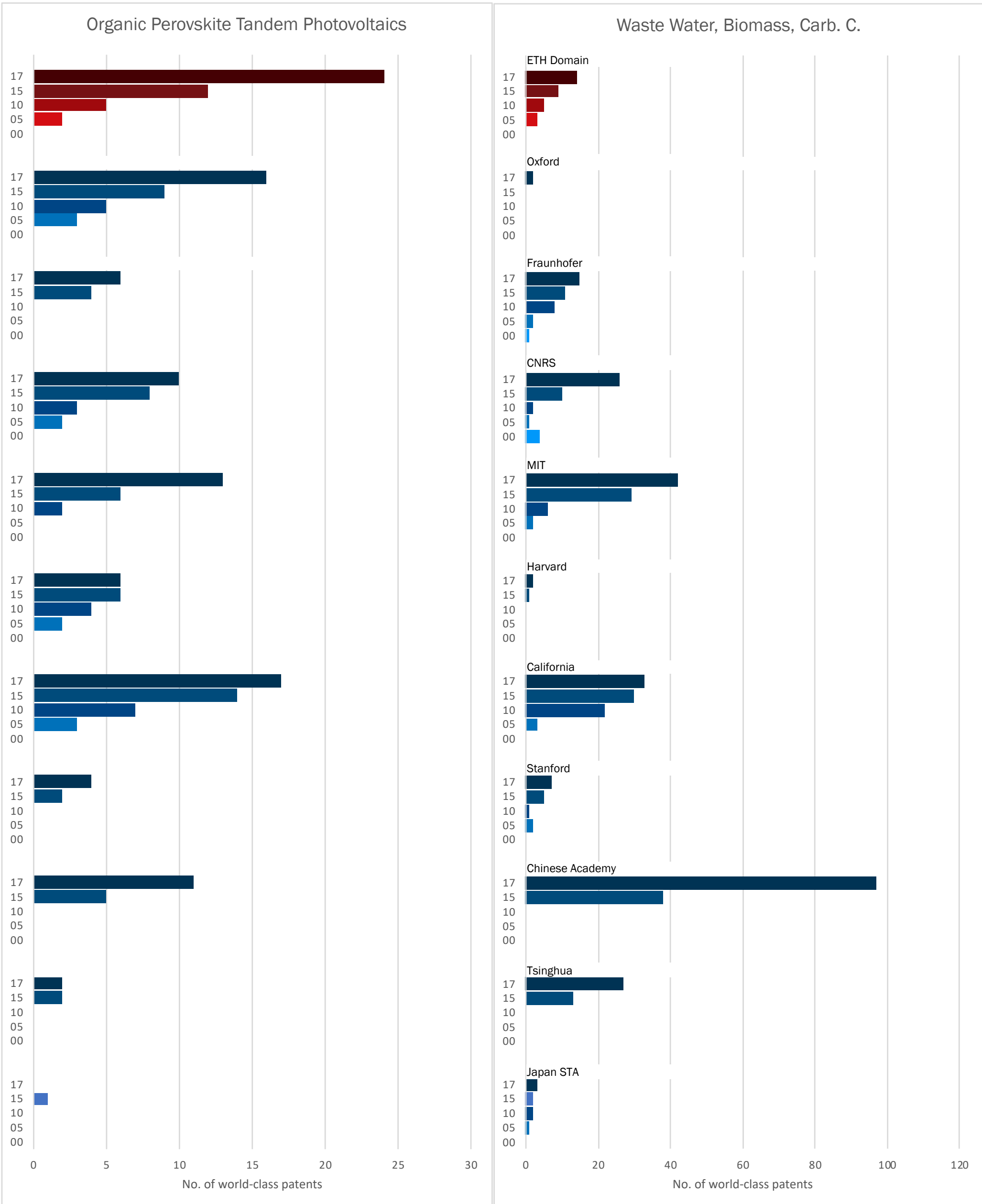
Similar to the national analysis, where the ETH Domain is dominated by the major life sciences companies, the international picture shows a similar development.

The US institutions dominate protein engineering. Harvard has made a leap forward through strong development in recent years. From a European perspective only the CNRS can keep up and the ETH Domain remains on a lower level together with the other European institutions.

A similar picture can be seen in drug discovery systems. Again, the US-institutions dominate the development. European and Asian activities are almost non-existent and the ETH Domain is in line with its European neighbors.

Organic pharmaceutically active substances shows contrary developments. Whereas the University of California lost its lead, the CNRS was able to move ahead in recent years only to be overtaken by Harvard which again shows high growth rates. The ETH Domain has one world class patent in this technology.

Chart 4-6 Energy: Comparison of ETH Domain with international research institutions, world class patents, 2000-2017



Source: BAK Economics, IGE, PatentSight

Perovskite Photovoltaics is a technology of increasing importance for most of the institutions covered. The ETH Domain is clearly ahead with 24 world class patents in 2017 and was able to lead the development from the beginning of 2000. Strong growth in recent years put the ETH Domain clearly ahead of the other institutions and stabilized the lead in this technology.

In waste water, biomass and carbon capture most institutions are increasing their efforts. However, the dominance of the Chinese academy of sciences is clearly visible in this technology space. This was to be expected because renewable energy is a clear current focus for the Chinese research community.

4.3 Conclusion

The following table provides an overview of the international results. The heat map is organized horizontally and labels the institutions with the highest number of world class patents within a technology in green colour gradients and the institutions with the lowest numbers in red colour gradients. Vertically the number of similarly coloured cells indicate the number of high rankings (green) and low rankings (red) per institution.

Tab. 4-2 International comparison of world class patents per technology, 2017

	ETH Domain	CNRS	Fraunhofer	Oxford	Stanford	Harvard	MIT	California	Japan STA	Chinese AS	Tsinghua
Security Elements	17	0	58	0	0	1	0	1	0	0	0
Quantum Technologies	7	6	1	6	3	21	39	23	3	12	3
Digital Image Analysis	19	7	29	19	22	5	19	35	4	17	35
Advanced Materials	57	60	15	7	23	58	126	151	28	138	173
Nanostructures	48	76	21	22	36	147	203	260	44	95	209
Additive Manufacturing	0	3	9	0	5	70	47	13	1	8	3
Mass Magnet Spectroscopy	12	6	6	7	10	11	12	18	3	12	19
Drones	8	0	0	1	1	0	4	0	0	0	1
Radiation Detectors	16	0	2	0	0	0	4	1	1	4	12
Biosensors, Lab-on-a-Chip. Biopr.	16	19	5	10	22	123	61	74	7	8	9
Wearables Bionics	9	0	5	1	6	11	32	24	1	3	0
Radiation Diagnosis and Therapy	22	7	2	3	15	7	16	33	0	6	25
Protein Engineering	40	86	10	47	86	288	218	232	15	25	12
Drug Discovery Systems Biology	1	1	0	0	15	42	28	23	0	0	1
Pharmaceutically active Subs.	1	12	0	1	0	15	4	11	0	5	0
Perovskite Tandem Photovoltaics	24	10	6	16	4	6	13	17	0	11	2
Waste Water, Biomass, Carb. Cap.	14	26	15	2	7	2	42	33	3	97	27
Total world-class patents	**311**	**319**	**184**	**142**	**255**	**807**	**868**	**949**	**110**	**441**	**531**

Source: BAK Economics, IGE, PatentSight

The ETH Domain has clear advantages in the systems technologies such as mass spectroscopy, drones and radiation detectors. It is also ahead in security elements where there are almost no viable competitors. Another strong development can be observed in perovskite photovoltaics. Overall, the ETH Domain is among the leaders in more than one third of all technologies analysed. This is an impressive achievement, especially against the major US institutions. In most other technologies, the ETH Domain shows a solid level of development, and remains ahead of most of the European competition. Apart from being better positioned than other European institutions analysed, the ETH Domain is also better positioned than most Asian institutions. However, it must be noted that Tsinghua University has seen substantial growth in patent quality in a wide range of the 17 technologies and is already ahead of the ETH Domain. The US-institutions, especially Harvard, MIT and the University of California System, are clearly leading the institutions analyzed in most technologies.

5 Contributors to the study

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