Analysis of biotechnology sector in Slovenia- identification of needs and opportunities for accelerating growth potentials

TRAIN PROJECT

21. FEBRUAR 2019

SIS-EGIZ FOR TECHNOLOGY PARK LJUBLJANA LTD
www.sis-egiz.eu & www.tp-lj.si

Analysis of biotechnology sector in Slovenia- identification of needs and opportunities for accelerating growth potentials

Biotechnology refers to a vast area of industries involved in the use of living organisms, their parts or by-products in industrial applications. The term Biotechnology can refer to a wide range of applications from a vaccine, developing new sources of biofuel, genetic modification of crops, beer brewing and even anti-aging cosmetics and cell-based products. All biotechnology areas share the need for bio-process engineers, microbiologists, cell biologists, automation engineers, equipment specialists, research scientists and bio-chemical engineers as well as (lately) for bioinformatics.

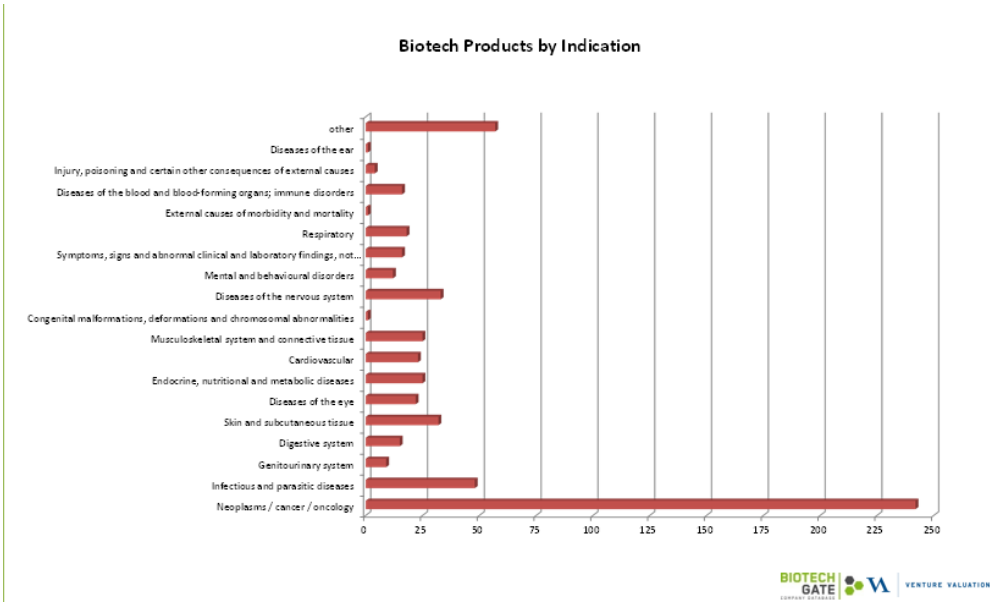
Main areas of biotechnology according to some classifications[1] can be classified into red, white, yellow, grey, green and blue biotechnology sectors:

Red biotechnology is usually referred as biopharma that connects stakeholders in medicine and veterinary products.	Products and services in this category include vaccines and antibiotics, developing new drugs, molecular diagnostics techniques, regenerative therapies and the development of genetic engineering to cure diseases through genetic manipulation.
White biotechnology is often referred to industrial biotech involved with designing low resource-consuming processes and products, making them more energy efficient and less polluting than traditional ones.	An example of white Biotech is the use of microorganisms in chemical production, the design and production of new plastics/textiles or bio-fuels.
Yellow Biotechnology, has been used to refer to the use of Biotechnology in food production	Making wine, cheese, and beer by fermentation.
Grey Biotechnology refers to environmental applications, and is focused on the maintenance of biodiversity and the removal of pollutants/contaminants using microorganisms and plants to isolate and dispose of different substances such as heavy metals and hydrocarbons.	Biodegradable plastics, production of industrial products through living systems (plants, animals and microbes).
Green Biotechnology is focused on agriculture. This area of Biotech is based exclusively on transgenics (genetic modification) i.e. they have an extra gene or genes inserted into their DNA. The extra gene may come from the same species or from a different species.	Green Biotechnological approaches and applications include creating new plant varieties of agricultural interest, producing biofertilizers and biopesticides.
Blue Biotechnology is based on the exploitation of marine resources to create products and applications of industrial interest. Taking into account that the sea presents the greatest biodiversity, there is potentially a huge range of sectors to benefit from the use of this kind of Biotechnology.	Algae for cosmetic use, jellyfish to help map brain neurons or medical grade collagen to treat bones and wounds.

In markets with high levels of biotechnology intensity additional market segmentations can be made also within each of the biotech categories such as shown in the example of the red biotech in Germany. No such classifications exists in the currently available databases in Slovenia and the few companies in Slovenia operating in the red biotech sector develop products in more than one of the biotech indication domains as described below. Further

[1] https://www.lscconnect.com/what-is-biotechnology/; http://european-biotechnology.net/

market segmentation by product indication would need to be developed in the future such as is shown in the case of German red biotech bellow.



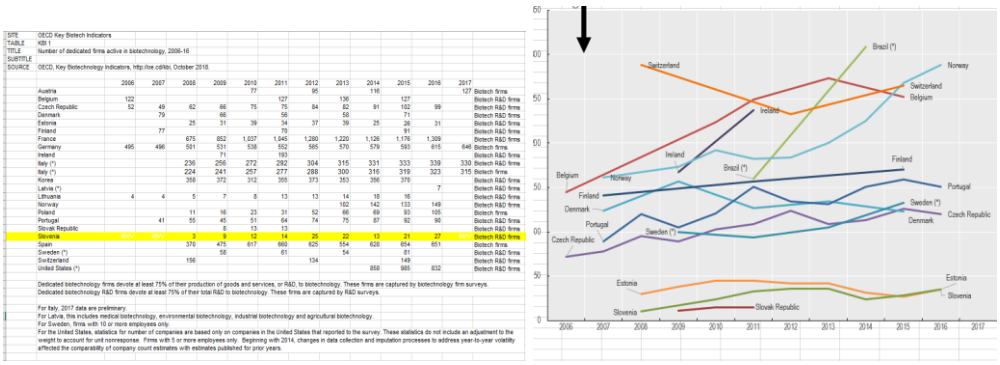
Source: http://resourcecenter.biotechgate.com/2017/10/german-life-sciences-trend-analysis-2017/#sthash.5OuvK8rp.dpbs

In addition to variety of biotech companies the innovation ecosystem as the key market for SME"S in this field consists also of numerous interdisciplinary research groups active in research and development platforms and networks such as in the COBIC Center of Excellency i.e. the CEBI- Center for biotechnology where basics and applicative researches are conducted as well as in the scope of the research groups in the national research institutions.

In the context of the project TRAIN the focus is in the biomedicine/biopharmaceutical segment of biotech with the possible convergence of biomedicine/biopharmaceuticals with the bioinformatics areas of research and industry including the ones relevant for the TRAIN research groups as one of the trends in the niche market growth is also a convergence of biotech with other disciplines such as bioinformatics where potentials for economic growth exists as well.

Market potentials

According to OECD reports the growth of biotech companies in last decade was significant all over Europe and globally. In Slovenia there were 27 active biotech companies in 2017. These were the companies that dedicate at least 75% of their total R&D expenditure in biotech (see table below).

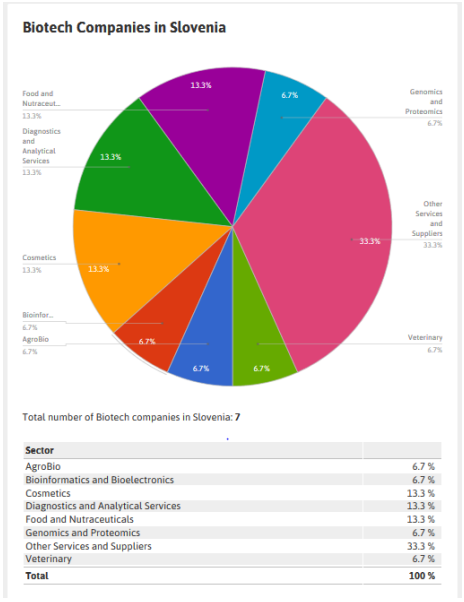


SITE	OECD Key Biotech Indicators												
TABLE	KBI 1												
TITLE	Number of dedicated firms active in biotechnology, 2006-16												
SUBTITLE													
SOURCE	OECD, Key Biotechnology Indicators, http://oe.cd/kbi, October 2018.												
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
	Austria					77		95		116			127	Biotech firms
	Belgium	122					127		136		127			Biotech R&D firms
	Czech Republic	52	49	62	66	75	75	84	82	91	102	99		Biotech R&D firms
	Denmark		79		66		56		58		71			Biotech R&D firms
	Estonia			25	31	39	34	37	39	25	26	31		Biotech R&D firms
	Finland		77				79				91			Biotech R&D firms
	France			675	852	1,037	1,045	1,280	1,220	1,126	1,176	1,309		Biotech R&D firms
	Germany	495	496	581	531	538	552	565	570	579	593	615	646	Biotech firms
	Ireland				71		193							Biotech R&D firms
	Italy (*)			236	256	272	292	304	315	331	333	339	330	Biotech R&D firms
	Italy (*)			224	241	257	277	288	300	316	319	323	315	Biotech firms
	Korea			368	372	312	355	373	353	356	379			Biotech R&D firms
	Latvia (*)											7		Biotech R&D firms
	Lithuania	4	4	5	7	8	13	13	14	18	16			Biotech R&D firms
	Norway								162	142	133	149		Biotech R&D firms
	Poland			11	16	23	31	52	66	69	93	105		Biotech firms
	Portugal		41	55	45	51	64	74	75	87	92	96		Biotech R&D firms
	Slovak Republic				8	13	13							Biotech R&D firms
	Slovenia	[x]	[x]	3	9	12	14	25	22	13	21	27	[x]	Biotech R&D firms
	Spain			370	475	617	660	625	554	628	654	651		Biotech firms
	Sweden (*)				58		61		54		61			Biotech R&D firms
	Switzerland			156				134			149			Biotech R&D firms
	United States (*)									858	985	832		Biotech R&D firms

Dedicated biotechnology firms devote at least 75% of their production of goods and services, or R&D, to biotechnology. These firms are captured by biotechnology firm surveys.
Dedicated biotechnology R&D firms devote at least 75% of their total R&D to biotechnology. These firms are captured by R&D surveys.

For Italy, 2017 data are preliminary.
For Latvia, this includes medical biotechnology, environmental biotechnology, industrial biotechnology and agricultural biotechnology.
For Sweden, firms with 10 or more employees only.
For the United States, statistics for number of companies are based only on companies in the United States that reported to the survey. These statistics do not include an adjustment to the weight to account for unit nonresponse. Firms with 5 or more employees only. Beginning with 2014, changes in data collection and imputation processes to address year-to-year volatility affected the comparability of company count estimates with estimates published for prior years.

Source: http://www.oecd.org/innovation/inno/keybiotechnologyindicators.htm



Total number of Biotech companies in Slovenia: **7**

Sector	
AgroBio	6.7 %
Bioinformatics and Bioelectronics	6.7 %
Cosmetics	13.3 %
Diagnostics and Analytical Services	13.3 %
Food and Nutraceuticals	13.3 %
Genomics and Proteomics	6.7 %
Other Services and Suppliers	33.3 %
Veterinary	6.7 %
Total	**100 %**

Source: https://www.slovenianbiotech.com/sln/portal/stats_sectors.php

One of the biggest areas of applications of the red biotech globally is pharmaceutical industry that employs in Europe 750.000 people and total market value estimated is 202 billion Euro (in 2016).

INDUSTRY (EFPIA total)	2000	2010	2015	2016
Production	127,504	199,400	238,437	250,000 (e)
Exports (1) (2)	90,935	276,357	365,303	375,000 (e)
Imports	68,841	204,824	269,012	275,000 (e)
Trade balance	22,094	71,533	96,291	100,000 (e)
R&D expenditure	17,849	27,920	33,557	35,000 (e)
Employment (units)	554,186	670,088	739,499	745,000 (e)
R&D employment (units)	88,397	117,035	113,713	115,000 (e)
Total pharmaceutical market value at ex-factory prices	89,449	153,685	193,742	202,000 (e)
Payment for pharmaceuticals by statutory health insurance systems (ambulatory care only)	76,909	129,464	131,685	134,000 (e)

Values in € million unless otherwise stated
(1) Data relate to EU-27, Norway and Switzerland since 2005 (EU-15 before 2005); Croatia and Serbia included since 2010; Turkey included since 2011; Russia included since 2013
(2) Data relating to total exports and total imports include EU-28 intra-trade (double counting in some cases)
Source: EFPIA member associations (official figures) – (e): EFPIA estimate; Eurostat (EU-28 trade data 2000-2016)

The Pharmaceutical Industry in Figures (EFPIA)

https://www.efpia.eu/media/219735/efpia-pharmafigures2017_statisticbroch_v04-final.pdf

Companies interviewed in this project TRAIN predominantly sell and market their products and services either to larger domestic and foreign biopharma or medical technologies companies or conduct research in the scope of the governmental grants, EU supported grants and/or publicly funded institutions such as domestic and foreign larger research institutions, clinical environments and/or national public health and food safety organizations.

A small sample of biotech companies interviewed for the purpose of this analysis shows that there is a great diversity and variety of biotech products/services that companies produce such as:

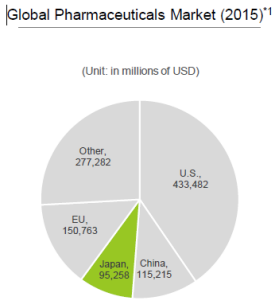
- services/products related to confocal microscopy, scientific research in neuroglia and technologies for the production of hybrid cells for use in cancer therapy through immunomodulation (Celica)
- production of bacteriophages and plasmid DNA and recombinant proteins production of biomolecules, stability studies, contract analytical testing, manufacturing of active pharmaceutical ingredients or drug substances and drug products (API/DS/DP), preparation of virus and cell banks, development and scaling up manufacturing processes (Jafral)
- validation/verification of analytical procedures (HPLC, GC, dissolution) for assay, related substances, degradation products, residual solvents, cleaning validations (swabs and eluates), analytics of cell-free DNA and liquid biopsies, analytics and development of GMO organisms and cell lines. (Labena)
- strain development though directed evolution and synthetic biology, fermentation process, development of downstream processing steps in development of bioprocess technologies, chemical synthesis processes (i.e. new methodologies), fine tune key bioprocess parameters, producing ingredients for rare disease treatments, new antibiotics based on resistant bacteria, new processes for vitamins production and other molecules for pharmaceutical, food, agriculture and chemical industry (Acies bio)
- small genomics research i.e. research with bacteria, viruses, fungus (Omega)

In the domain of the red biotechnologies there are global trends also indicted by the companies in Slovenia towards development of the so called advanced therapies i.e. “omics” in combination with the support of the bioinformatics in areas such as big data management, imaging, sequencing, artificial intelligence, cybersecurity.

Based on some available resources briefly described in the table, the following key market trends relevant and applicable also for Slovenia”s future development of the red biotech companies could be identified. A more thorough and detailed investigation on the market trends and potentials for Slovenia would have to be conducted in the near future to address more thoroughly some of the issues identified in the scope of this preliminary market analysis in largest biotechnology markets such as Germany, Switzerland, Scandinavia in Europe and Japan in Asia (as Japan is a partner with many R&D intensive companies in Slovenia already).

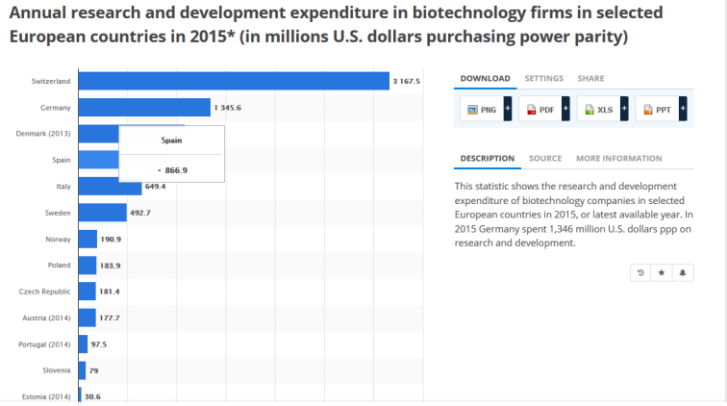
In Germany, being also one of the key geographical markets for Slovenia”s biotech companies[1]it is expected that all sectors of industries are making increased use of bio-based processes and products and that the value added chains are being supplemented with biological components in the wake of bioeconomy growth. This effects of the biotech expansion across various industries and value chains also has to be taken into consideration with the forecasting the market potentials of biotechnology with the **three key fields** contributing the most to the overall growth of bio-economy globally: agricultural (green) biotechnology (such as GMO in USA and research related to it done also by global biotech leaders in Europe), industrial (white) biotechnology (enzymes and biofuels taking the lead) and medical (red) biotechnology with biopharmaceuticals, oncology, biosimilars, generics and conventional/generic drugs (mostly due to expiration of patent protection as they represent cheaper alternative to original drugs). It is estimated that by 2020 the worldwide sales volume with biopharmaceuticals only will reach over USD 280 billion! Similarly, for example cancer costed the EU €126 billion in 2009, with health care accounting for €51·0 billion (40%).[2]

In biopharmaceuticals the global market distribution share is represented also in the chart below [2]



Source: JETRO Invest Japan Business Support Center report: Market report on biopharmaceuticals produced in 2017

2 JETRO Invest Japan Business Support Center report: Market report on biopharmaceuticals produced in 2017 where Japan ranks as a third largest global market. It is also indicative that from 10 new drugs approved in Japan 4 were from foreign companies, including 2 developed by Sandoz.



Source: OECD

Another biggest market area for biotech is also chemical industry where R&D expenditure is expanding as well. Similar is the case of agriculture and food production, environment and marine industry where a detailed analysis of the potentials for Slovene biotech companies has to be made as well.

FACTS & FIGURES of the European chemical industry, CEFIC 2018

<u>Challenges & global market trends in red biotech</u>

- Biologics market faces competition from biosimilars and bio betters
- Emphasis is on value for patients not on research
- Enormous risks involved with high investments, higher expectations (9 out of 10 drugs developed fail)
- Prices of big pharma are going down
- R&D is getting outsourced
- Business models of companies are changing from marketing oriented to products meaningful in life
- Rapid advances in sciences
- Hyper cycle (existing discoveries are overvalued)
- Biotech is maturing
- Deeper understanding of molecular biology of disease
- New tools for detecting targets are developed
- Ecosystem of health care is changing,
- Costs of drugs are lowering
- Dealing with societal needs such as neurodegenerative diseases, cancer disease and metabolic disease
- Evolution of targeted drugs and nanomedicine
- Societies will determine pricing not companies (changes in pricing models)
- Rare diseases are easier to manage due to global patient groups and big data analytics
- New models of innovation and new regulations

- Machine learning is utilized for better understanding of genomics, vaccine design, drug repurposing, better understanding of diseases, genetic markers for personalized medicine
- Patents on key products are expiring
- Informed and active stakeholders are demanding value and transparency over business practices
- Regulations are more complex and strictly enforced

Convergence of biotech and bioinformatics

One of a key challenges explored in the context of the Train project was possibility for bioinformatics and biotech companies to converge and collaborate in certain areas. Several possibilities have been identified but few convergences insofar were found (sequencing data, data protection and sharing, data analytics) such as:

- Integrating methods for predicting structural values, biological data analytics/exchange and security, machine learning, artificial intelligence, imaging
- Data on patients (blood samples, health records, genes & environments, prescriptions, targeted drugs-consortiums for data gathering)
- Data analytics and interpretation and sharing
- Imaging techniques
- Data manipulation
- Data analytics/info graphics, info presentations
- Imaging (ex. Brain imaging)
- Virtual reality environments
- Data aggregation of patients' cohorts
- Identification of biomarkers
- Trajectory of diseases
- Accessing genetic data (for cancer)
- Translating data to users (researchers)
- Data sharing
- Data encrypting/protecting/securing
- Open access data
- Standardization of data
- Data crossing/transferring (from research area to research area)
- Game programming for patients (ex. Alzheimer, blindness)
- Trajectory of disease (modification of age and genetics)
- Data integration
- Mobile health
- Captioning info on personal activities on computers (data integration)
- Training next generation of medical professionals on data storing and application
- (data science in academic world- next generation of investigators)
- Understanding complex emerging systems
- Deep learning
- Data mining
- Machine learning (learning from clinical data)- supervised machine learning
- Interchangeable algorithms (richer data- what matters and corelates will be considered)
- Data use for predictive medicine: more data taken to measure more precisely, more tolerancy with predictions will develop, data will be moving
- Technology will be used to solve problems based on your own preferences (democratization of health care)

- Development of a value based care
- IAI will have bigger impacts than in other areas of industry
- Data mining in health care & economic issues will come to the forefront of care
- Patterns recognition in gene expression

Slovenia- biomedicine development- some current developmental challenges

In the scope of the Strategic research and innovation partnership in Health and Medicine[3] value chains have been created to advance certain areas of research in medicine. Six areas have been identified where value chains have been formed: translational medicine, biopharmaceuticals, cancer treatment, resistant bacteria, active healthy aging and herbal medicine and cosmetics. The latest research in biomedicine is covering topics such as new diagnostic biomarkers, development of new target substances, discovering markers in pharmacogenomics, finilizing development of CD34 cell therapeutical products for hematological and oncological indicators and therapies.
SWOT analysis of red biotechnology companies' potentials in Slovenija (SME only)- based on observations of the interviewed companies and SRIP Health-Medicine (Smart specialization)

Strengths	Weaknesses
Excellent research capabilities in all areas relevant to biotechnology (biology, medicine, bioengineering, bioinformatics); Mix of dynamic SMEs ('Drivers of Innovation') and global players in the chemical, food and pharmaceutical industries (Lek, Krka et al.); Highly skilled academic and non-academic workforce Competences in R&D based industries. High business funding of academic research, due to favorable fiscal policy and regulation. Safe, family and nature friendly environment.	Underdeveloped culture of knowledge transfer (focus on knowledge, R&D production, lack of validation and commercialization of ideas); Lack of venture capital; Lack of integrated 'funding instruments for mitigating risks (public grants, seed-funding, venture, IPOs) Companies focus on service and supplier roles Imbalances between fundamental research and applied research in certain areas of biotech. Insufficiently developed business support environment (hardly existing risk capital, innovation system not developed and non-attractive business regulations for investments); Low high-tech export and knowledge based services. Underdeveloped intellectual property use and commercialization of intellectual rights.
Opportunities	Threats
Biotechnology as a cross-sectional technology with wide application potentials in many industrial sectors; Participation in the global transformation of the chemical, agricultural, marine, environmental and pharmaceutical sectors. Biotechnology as a knowledge-based industry has potentials for creation of high quality jobs in new industries, thus great potentials for creating high value added products/services. Biotechnology enables and supports development of sustainable national economy.	Companies and brains are moving abroad due to lack of skilled resources and incentives; Underdeveloped ecosystem to support needed and a necessary structural balances between academia, research and industry. Weak commercialization of research due to low public acceptance of biotechnology (e.g. genetic engineering, genome editing in relation to bioethical issues) Loss and lack of core competences in bioengineering and bioinformatics. Lack of funding and incentives for start-ups and scale-ups to accelerate growth of companies, resulting in

[3] https://www.sripzdravje-medicina.si/

Development of smart bio-based production. technologies introducing principles of the industry 4.0' to production and manufacturing. Few successful companies focus on the development of active pharmaceutical ingredients (with high potential ROI). Enable mission-oriented public funding (biotechnology to solve key societal problems: aging, healthy environments)	loss of competences in the design, development and production in the medium term. Risk averse culture.

Recommendations for improvements of the red biotech sector in Slovenia

Competences

Competence models for developing key skills needed in biotech are being developed with the joint efforts of industry, academia and government in the scope of Slovenia"s regional specialization strategy covering also various areas of competences relevant for the red biotech sector.[4] In the case of biomedicine these are competences in areas of molecular biology, pharmacy, ICT-bioinformatics, hardware and software development and management for laboratories. Besides technical and specialized bio-based skills also business skills, project management skills, quality control skills, marketing, communications, negotiation and digitalization and critical thinking skills are needed. To successfully embark onto the needs of the industry 4.0. also interdisciplinary skills are needed. In the framework of a competence development project in biopharmaceutical industry 50 professional competences were identified, 14 leadership competences, 8 social and 15 digital totaling 87 various competences. In the field of biotech a special more complex and less specific set of numeric skills are necessary to be considered in the future as well (called STEM quantitative skills- advanced math and statistics), mostly needed in areas of engineering and technologies and bioinformatics/biostatistics.[5]

Employment

- Increased efforts have to be made to develop and use incentives for employment and models to attract talents in business sector (by enabling circulation of researchers and others from academia to business and vice-versa and by favorably taxing highly skilled professionals);
- Develop global talent acquisition schemes and practices (also by business support organisations Technology park, Employment agencies etc.)

Financing

- Increase financial investments in R&D, innovation and entrepreneurship by reforming system of publicly funded R&D to reach 1% GDP funding to reach 3.0% GERD funding jointy with the investments made by the companies

Legislation

[4] Projekt: Kompetenčni center za razvoj kadrov v biotehnologiji in farmaciji Bio-Pharm, COBIK in SIS EGIZ, 2018
Grundke, R. *et al.* (2017), "Skills and global value chains: A characterisation", *OECD Science, Technology and Industry Working Papers*, 2017/05, OECD Publishing, Paris. http://dx.doi.org/10.1787/cdb5de9b-en

[5]

- Revision of industrial legislation to enable favorable conditions for investments into R&D also for private individuals (instead of bank savings).
- Regulatory/system support to the national innovation system has to be developed or improved in order to better cultivate key sectors of economy such as biotech i.e. enable conditions for building innovation capacity (support with providing sufficient future oriented technical knowledge, create risk prone, future and global market oriented entrepreneurship and provide instruments for higher risks investments pertinent to the new technologies in biotech).

Strengthen internationalization efforts and global value chains creation also by such measures as:

- attracting foreign partners for joint enterance to global markets, joint products/services development and creation of global value chains.
- support organization and participation at global business/scientific conferences and fairs
- better use of economic representations of Slovenia abroad for information (intelligence gathering), promotion and communication about the biotech sector

Other measures

- Increase support with creating a risk prone and globally opened culture by strengthening actions of the business support environment such as creation of a more vibrant and opened innovation system including technology parks, funding agencies, incubators, tax and regulatory authorities, education institutions etc. to encourage researchers to take proactive actions towards entrepreneurial careers.

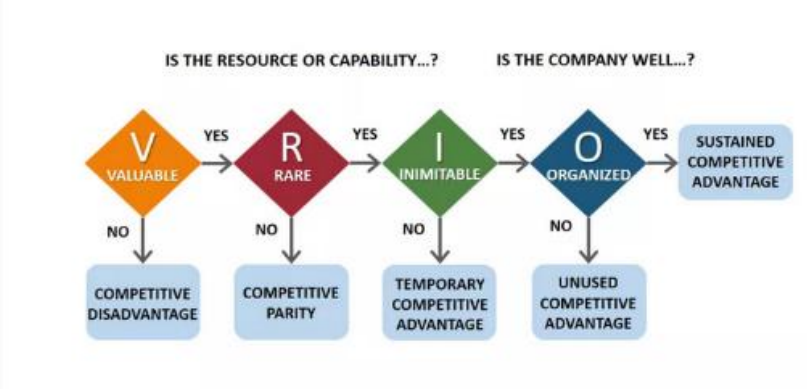
Technology transfer

- Increase efficiency of R&D investments also by better exploitation of the intellectually property rights and technology transfers (provision of services, trainings of tech transfer officers, patent offices, quality certification agencies etc.)
- With setting up a national reference point for Technology transfer at the Institute of Joseph Stephan in 2018 it is expected in the future that improvements will be made in efficiency of registration and exploitation of intellectually property rights. Training courses, workshops and seminars also presenting good practices should be organized for the biotech companies by the Ljubljana technology park in collaboration with other support organisations, companies (for example quality control) and governmental agencies.

- Strategies for successful launching of innovations on the markets

It is recommended that Technology park jointly with other partners provides trainings and courses on using managerial tools to better utilize companies internal resources and managerial capacities (for example such as VRIO strategy, value change creation strategic tools etc.)

VRIO STRATEGY



Other measures and recommendations in the scope of this project in biotech to be successfully launched on global markets can be as well:

- Market intelligence gathering (including utilization of a vast network of international diplomatic services)
- Better understanding and utilization of the market entry incentives and opportunities for foreign companies given by many global markets and biotech hubs and recently supported by the European Union programmes (utilizing financial support/incentives, subsidizing participation at international events for EU based companies): https://ec.europa.eu/growth/smes/access-to-markets/internationalisation/support-tools_en
- Active participation and incentivizing of the players at the international conferences and fairs by providing a more targeted internationalization programmes as carried on by the national internationalization agency SPIRIT

- Process of technology transfer and competences

Some good practices from developed biotech ecoystems could be found as for example in Gemany (patent registrations offices and IP support services developed around the biotech companies);
Switzerland (integrated services for the innovation support) or Scandinavia (fast track to public stock exchange programmes, tax deductible donations for R&D, programmes for circulation of researchers from business, academia and public institutions in biomedicine)

Source: Swiss biotech report 2018

- **Sustainable innovation policy & innovation policy instruments**

  As innovation has become faster, multidisciplinary, collaborative, democratized and global a new more sustainable models of the innovation policy need to be developed as well.

  Efforts have been made lately in Slovenia with establishment of the Slovenian innovation hub in 2016 to set up a vibrant innovation ecosystem with numerous proposals made so far to the quadruple helix stakeholders including the government to create and support of the national innovation policy and create sustainable innovation policy instruments.

  Major weakness were identified such as big fragmentation of R&D that prevents efficient technology transfer from research institutions into business environments and a very fragmented business support environments (there are over 120 organizations in the country that deal with technology transfer issues but no central body such as technology-innovation agency coordinating these actions). Efforts have been made and need further support by the Government to strengthen collaboration and reach critical mass of knowledge also through implementing regional specialization strategy in key sectors of national economy.

  Innovation policy is interdisciplinary and multiple sectoral policy need to collaborate. System of public funding of R&D needs reforms in order to reach the goal of 1% GDP funding. Elements of sustainable innovation ecosystem include entrepreneurs, investments in research and development, a vibrant and flexible education system in particular higher education, finances, especially seed and venture capital, competitive tax and regulatory environments and public policy institutions.

  A think thank organized by the Slovenian innovation hub in April 2017 "R&D activity as a base for technological break through" has been organized and the conclusions were that reforms are needed to set up a more innovation favored financial support environments (various instruments, risks mitigation), to modernize of legislation in some areas (industry, science and R&D, social, tax, internal company buy-outs etc.), reform of educational programs at all levels to better support needs of the industry and society of the future and mitigate global risks, strengthen social corporate responsibility and improve capital management (including human capital and bigger openness to foreign capital). Other recommendations were also to increase investments into technologies in combination with foreign trade investments and restore institutions supporting technology development using a model from Finland i.e. by setting up a national technology agency and reorganizing of the existing National Research Agency as well as an important institution giving support to restructuring some of the key sectors of economy from which industries are codependent (i.e. increase efforts for more sustainable energy production and use and modernize transport- railway/port).

[1] Vir: https://www.acatech.de/wp-content/uploads/2018/03/IMPULS_Biotechnologie_EN_KF_final.pdf

[2] Vir: The Lancet Oncology, **Economic burden of cancer across the European Union: a population-based cost analysis,** Ramon Luengo-Fernandez, DPhil , Dr Jose Leal, DPhil Prof Alastair Gray, PhD Prof Richard Sullivan, MD, Ocotber 2014, https://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(13)70442-X/fulltext

SOURCES

- https://www.acatech.de/wp-content/uploads/2018/03/IMPULS_Biotechnologie_EN_KF_final.pdf
- The Lancet Oncology, **Economic burden of cancer across the European Union: a population-based cost analysis,** Ramon Luengo-Fernandez, DPhil , Dr Jose Leal, DPhil Prof Alastair Gray, PhD Prof Richard Sullivan, MD, Ocotber 2014, https://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(13)70442-X/fulltext
- [2] Projekt: Kompetenčni center za razvoj kadrov v biotehnologiji in farmaciji Bio-Pharm, COBIK in SIS EGIZ, 2018 Grundke, R. *et al.* (2017), "Skills and global value chains: A characterisation", *OECD Science, Technology and Industry Working Papers*, 2017/05, OECD Publishing, Paris. http://dx.doi.org/10.1787/cdb5de9b-en
- What is biotechnology: https://www.lscconnect.com/what-is-biotechnology/
- European biotechnology network: http://european-biotechnology.net/
- Innovation potenials of Biotechnology, acatech National Academy of Sciences, IMPULSEExecutive Summary: https://www.acatech.de/wpcontent/uploads/2018/03/IMPULS_Biotechnologie_EN_KF_final.pdf
- Biotech Gate Global: http://www.biotechgate.com/web/cms/index.php/start.html
- Swiss Biotech report 2018: https://www.swissbiotech.org/sites/swissbiotech.org/files/webmasterfiles/swissbiotechreport/swiss_biotech_report_2018.pdf
- The Pharmaceutical Industry in FiguresKey Data 2017: https://www.efpia.eu/media/219735/efpia-pharmafigures2017_statisticbroch_v04-final.pdf
- The European Chemical Industry Council: http://www.cefic.org/Facts-and-Figures/
- Annual research and development expenditure, OECD; https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm#indicator-chart

Own sources of information on trends in biotech and bioinformatics

-

Biotech: Bull Market or Bubble? https://www.youtube.com/watch?v=pkc5A9PljBU&feature=youtu.be
Dr. Albert P. Kauch, Issues in Biotechnology CMB 190 Lecture 5 Trends, Patterns and Relationships in Biology;
https://www.youtube.com/watch?v=oduE3Bl2PI0&feature=youtu.be

Trends in Biotech Investing (Biotech Panel 2, YIS 2018);
https://www.youtube.com/watch?v=hXXYXUwqZ7Y&feature=youtu.be

How Machine Learning and Big Data Are Changing the Face of Biological Sciences;
https://www.youtube.com/watch?v=-Q447inB6YQ&feature=youtu.be

How machine learning helps cancer research" by Evelina Gabasova;
https://www.youtube.com/watch?v=vNiyDbcfJDE&feature=youtu.be

Deploying Predictive Analytics in Healthcare;
https://www.youtube.com/watch?v=yELeVBWOOQM&feature=youtu.be

Biotechnology/Nanotechnology | Andrew Hessel | SingularityU Germany Summit;
;;2017https://www.youtube.com/watch?v=XZfUJuSmBAs

»Not What but Why: Machine Learning for Understanding Genomics | Barbara Engelhardt; | TEDxBoston«https://mail.google.com/mail/u/0/#inbox/QgrcJHsNqLwXXVrkpDHqGGgLDQDKbgRrmvB?projector=1

Genomics, Big Data, and Medicine Seminar Series – George Church
https://www.youtube.com/watch?v=iVG4EaMrXfI&feature=youtu.be