# FORESIGHT ON

# NEWSLETTERS 2020

The objectives of the newsletter series 'FORESIGHT ON' are to raise awareness of and stimulate debate about trends, important emerging issues and their potential implications for Europe. The newsletters aim to support future thinking among policymakers (timeline 3-10 years), to trigger reactions and inspire strategies and long-term policies.

Volume 2020 of the FORESIGHT ON Newsletters consists of four newsletters produced in 2020. It includes:

**1. FORESIGHT ON Artificial Intelligence and Digital Transformation, produced on 19 February 2020**

**2. FORESIGHT ON Critical Raw Materials, produced on 9 March 2020**

**3. FORESIGHT ON Security, produced on 24 July 2020**

**4. FORESIGHT ON Health, produced on 19 November 2020**

We should not forget that 1) news is timely and 2) we cannot predict the future. Therefore, despite the forward-looking content of the stories, the information could only be up-to-date at the time of publication. However, for many stories the key messages and trends remain the same today. For other stories, there has been an acceleration of the trend and/or changes in data distribution, details, key players and some situations have naturally evolved. For example:

The World Health Organisation declared the COVID-19 pandemic on 11 March 2020 and it is not over yet. How important COVID-19's impact would be on each topic was estimated at the time of writing. In some cases, it was mentioned, and in others, it was not.

1.The newsletter on Artificial Intelligence (AI) was produced at a time when we still believed that coronavirus would be contained. Following the worldwide lock-downs due to the pandemic, there has been a strong push for digital transformation in all spheres of life: from telework to digital education, online shopping and communication.

2. The Critical Raw Materials Newsletter briefly discussed the pandemic as the first disruptions were being felt at the beginning of March 2020 across factories in Europe and elsewhere.

3. The Security Newsletter discussed vulnerabilities across critical infrastructures due to the pandemic.

4. The Health Newsletter focused quite a bit on COVID-19, though the situation has evolved. Today there are successful new vaccines and programs underway across the EU and beyond. Vaccine nationalism seems to have become a reality and the use of vaccines as a geopolitical instrument is growing. The long-term problem of antibiotics being used inappropriately by individuals and in healthcare settings is worsening because of the pandemic, and Europe now risks an accelerated spread of antimicrobial resistance (AMR).

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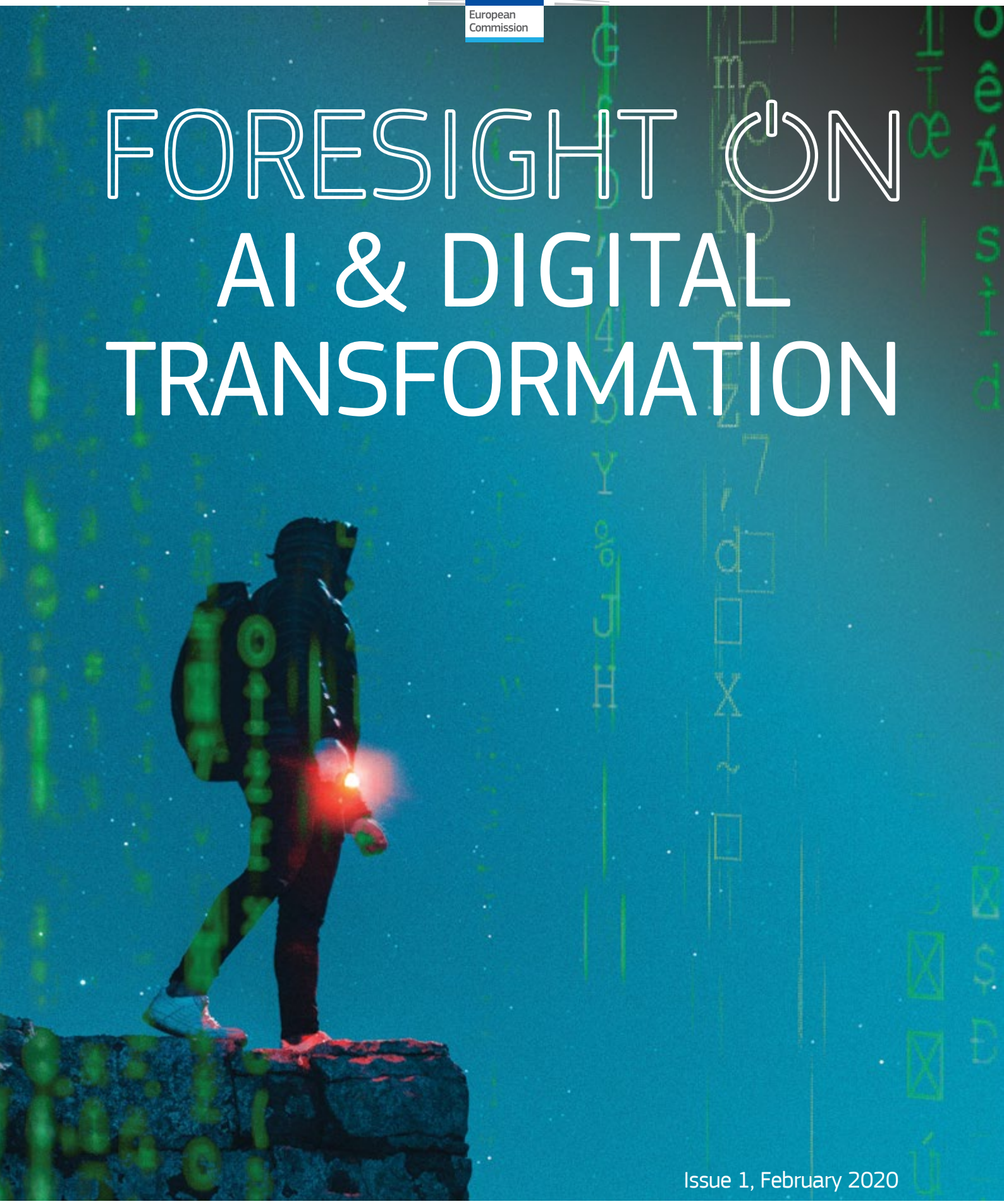
European Commission

# FORESIGHT ON AI & DIGITAL TRANSFORMATION



Issue 1, February 2020

Joint research centre

## WHY A FORESIGHT NEWSLETTER?

The objectives of the newsletter "FORESIGHT ON" are to raise awareness and stimulate debate on trends, important emerging issues and potential implications, as well as to support future thinking (timeline 3-10 years) among policymakers, to trigger reactions and inspire strategies and long-term policies. The primary audience is the College of Commissioners and the senior management of Directorates-General.

This foresight newsletter looks forward at key challenges and opportunities that future European policies on AI might need to address. The intention of the newsletter is to enlarge the discussions by highlighting forward-looking questions backed by recent facts and figures, related to Artificial Intelligence. The objective is not to be comprehensive but to shed light on relevant issues for European policymaking.

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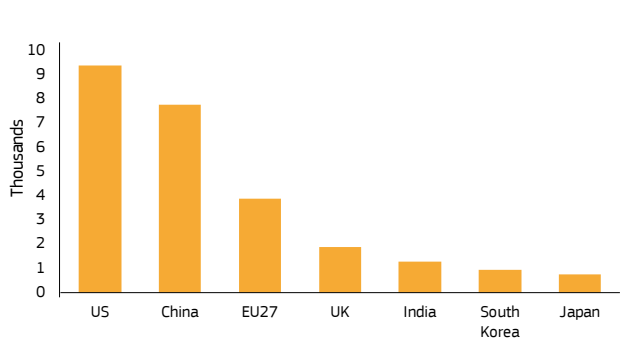
## STRATEGIC STRENGTHS AND WEAKNESSES, THE NEW AI BOLLYWOOD?

Many countries have been developing their Artificial Intelligence (AI) policy strategies. One of them is India,[1] who currently ranks 5th worldwide and is in the process of defining its new AI strategy for 2020. It has the biggest number of young firms, research institutes and government authorities (i.e. economic agents in the ecosystem) with an active role in AI and is showing promising potential to catch-up with the current global leaders (the US, China and the UK).

**Figure: Number of economic agents in the ecosystem (top 7)**




**Source: EC JRC, ongoing research**

In 2019, the AI and analytics industry was estimated at USD415 million in revenues, compared to **USD230 million in 2018**[2]. India's 2020 budget is likely to have the implementation of the National Centre on AI as a key priority, to push for better organisation in human-machine partnerships and better analysis of consumer patterns using big data. Indian industry expectations are that the 2020 budget will focus on the establishment of specialised centres for AI, Research & Development (R&D) labs and incentives for start-ups to enable them to compete against foreign players, such as China, and to ensure India's ability to scale up rapidly.

Alongside healthcare, AI investments will be directed to four other sectors: agriculture, education, smart cities & infrastructure and intelligent mobility & transportation.

In addition, India's demographic strengths - more than half of the population is under 25 years - reduces the problem of re-skilling dramatically and puts them in a strong position to become a world leader in areas such as Natural language processing (NLP).

Privacy is becoming paramount: India is looking to develop personal data protection and privacy laws in response to multiple privacy breaches and violations that occured in 2019.

## US DEBATES THE IMPACT OF THE AI STRATEGY

A year after the adoption of its AI strategy, debates are shaping the US AI field. **A draft Memorandum by the Office of Management and Budget from January 2020**[3] places an emphasis on having a light regulatory approach to favour competitiveness. This strongly pro-innovation approach differs markedly from the European human-centred one.

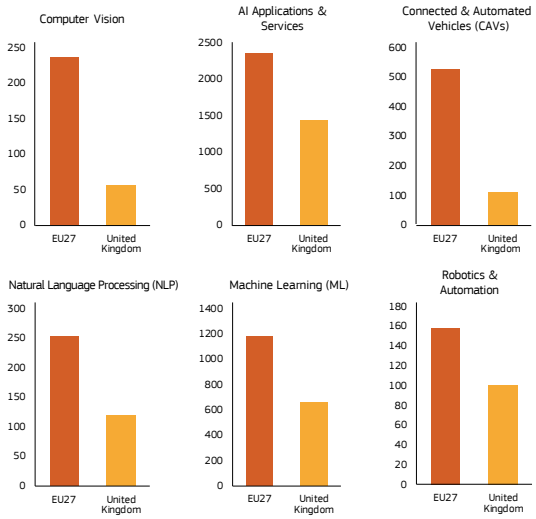
The expert report of the Center for a New American Security lists recommendations[4] for the US government. Some relevant ones are to:

- Boost annual US government funding of R&D on AI to USD25 billion, which would be equal to approx. 19% of total R&D spending in the Fiscal Year 2020 budget;
- Reform and simplify the US visa application process to make it more suitable for hiring and retaining international talents;
- Combat illicit technology transfer by providing more cyber defence support to small firms and small and medium businesses, as these are more vulnerable to cyber-attacks;
- Improve collaboration between US universities and counterintelligence experts;
- Protect US research from supporting human rights violations;
- Increase the availability of affordable computer resources. The the high cost and limited opportunity to compute is often a barrier for startsups and researchers in academia;
- Boost domestic semiconductor manufacturing with retooling incentives; and
- Secure sustainable procurement for defence through public-private partnerships.

## AI LEADERSHIP AFTER BREXIT

Following the UK's exit of the European Union, it is important to examine the impact of Brexit on the competitive edge in AI and what implications there are for the EU's AI strategy. For example, the number of AI firms in the UK is almost half of the firms in EU27. In the period 2009-2018, in the sectors of Natural Language Processing, Machine Learning and especially Robotics and Automation, the UK's share of EU activities was relatively large, at 32-38%.

**Figure: EU vs. UK - Number of actors**



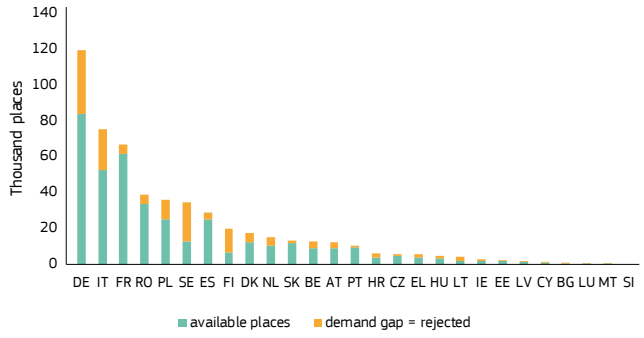

**Source: JRC report "TES analysis of AI Worldwide Ecosystem in 2009-2018"[5]**

1. Joint Research Centre, ongoing research;
2. Analytics India Magazine, https://analyticsindiamag.com/budget-2020-tech-industry-expects-substantial-allocation-for-ai-projects/
3. Draft Memorandum for the Heads of Executive Departments and Agencies (2020), https://www.whitehouse.gov/wp-content/uploads/2020/01/Draft-OMB-Memo-on-Regulation-of-AI-1-7-19.pdf
4. The American AI Century: A Blueprint for Action, December 2019 by Center for a New American Security
5. Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106.

## HOW TO FACE AI-SKILLS CHALLENGE?

Demand for skills in emerging technologies such as AI, high performance computing and cybersecurity are acute and the problem is growing - as demand lags behind supply. Beyond speculations on how AI will change the job market, it is certain that **AI skilled workers will be needed in all areas of society**[1]. The level of preparedness and awareness however, is not the same across the EU. There is a difference between the Master level education opportunities for AI, as well the demand for such education expressed by students in the EU.

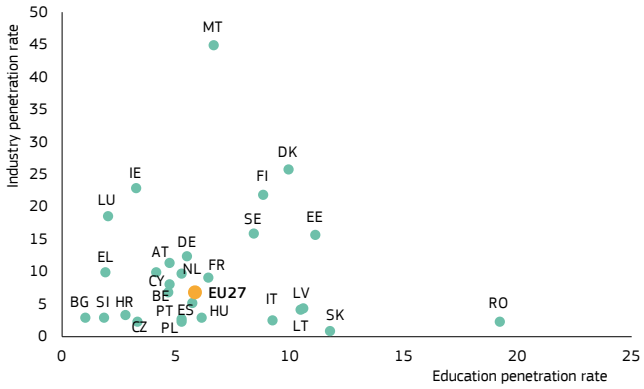
**Figure: Demand and availability of AI master studies**




**Source: EC JRC, 2019.**

The dynamics of offer/supply of trained individuals is rapidly growing, especially in countries such as Germany, Poland, France, Finland and Romania, but they still do not meet the increasing demand.

**Figure: Education vs. industry penetration**



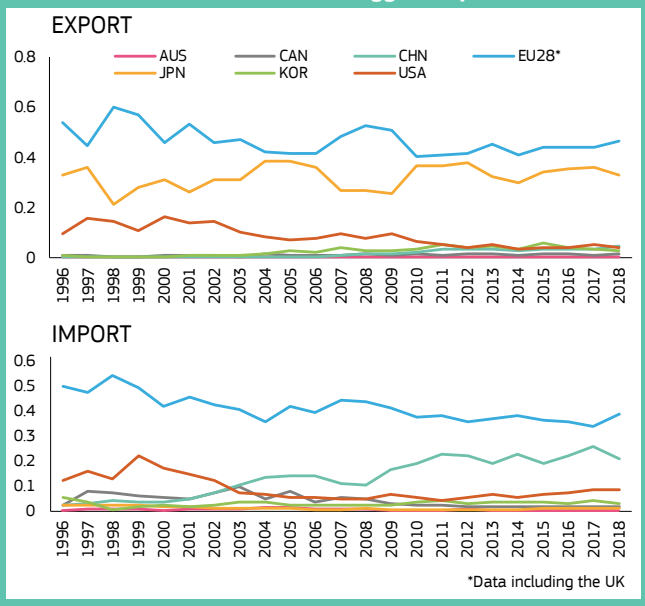

**Source: EC JRC, 2019. Academic offer and demand for advanced profiles in the EU. Artificial Intelligence, High Performance Computing and Cybersecurity.**[2]

The inadequacy of AI Masters education with respect to industrial counterparts, is shown by the relative position of their 'penetration rates' (i.e. number of AI programmes per 100 programmes) and in the industrial landscape (number of AI firms per 100,000 firms). Countries such as Romania, Slovakia, Lithuania, Latvia and Italy have a higher penetration rate of AI in education than expected, considering their lower AI penetration in industry. Ireland and Luxembourg have a strong industrial fabric in relation to the AI education on offer.

## HOW CAN EUROPE KEEP ITS COMPETITIVE EDGE IN THE NEW GENERATION OF ROBOTICS?

Robotics are moving from traditional robotics to smart robotics powered by AI. The EU28 was the biggest industrial robot exporter, with Japan being its main competitor. Their respective market shares seem to move in opposite directions. Moreover, while Japan's domestic demand seems to be satisfied almost fully by domestic production, the EU is producing and also importing from other global markets. China remains one of the biggest markets and trade partners for Europe, potentially entering more significantly into this tech field.

**Figure: The evolution of the export and imports market shares for the EU28 and the six biggest exporters**




**Source: ComTrade; EC JRC, 2019.**

## COMPETITION OVER DATA[3]

With the rapid rise of **the Internet-of-Things**[4], machine data is growing in importance. The question of who has control over it is becoming essential to avoid data monopolies.

Data is mainly collected by private firms who maintain exclusive control, **while maximizing its value**[5], though there are no legal ownership rights on data (except for those falling under the EU Database Directive). This can lead to the monopolizing of pricing and/or restrictions on the sale and re-use of data, **with serious implications for machine-learning applications that benefit from large, open, data pools**[6]. Competition authorities and data regulators should carefully balance the benefits of large data pools against **the disadvantages of reduced competition**[7] as business-to-business (B2B), direct and indirect data trade grows. Policy options for leveraging the potential of currently underused data include: technical interventions to reduce data trade costs through application programming interfaces (APIs) and standardisation of data formats; trade facilitation by third-party intermediaries to reduce transaction costs; and possibly mandatory data-sharing in certain cases.

1. JRC report (2019), https://ec.europa.eu/jrc/en/publication/academic-offer-and-demand-advanced-profiles-eu
2. López Cobo M., De Prato G., Alaveras G., Righi R., Samoili S. , Hradec J., Ziemba L.W., Pogorzelska K., Cardona M., Academic offer and demand for advanced profiles in the EU. Artificial Intelligence, High Performance Computing and Cybersecurity, EUR 29629 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-98983-4,doi:10.2760/016541, JRC113966: https://publications.jrc.ec.europa.eu/repository/handle/JRC113966
3. More information on European data strategy can be found here: https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en
4. Internet of Things (IoT) represents the next step towards the digitisation of our society and economy, where objects and people are interconnected through communication networks and report about their status and/or the surrounding environment. https://ec.europa.eu/digital-single-market/en/internet-of-things
5. Duch-Brown, Martens and Mueller-Langer, 2017. "The economics of ownership, access and trade in digital data," JRC Working Papers on Digital Economy 2017-01, Joint Research Centre. https://ec.europa.eu/jrc/sites/jrcsh/files/jrc104756.pdf
6. Martens, Bertin (2018) "The impact of data access regimes on artificial intelligence and machine learning," JRC Working Papers on Digital Economy 2018-09, Joint Research Centre.
7. Crémer, J., Y-A de Montjoye and H. Schweitzer (2019) Competition policy for the digital era, Report for Commissioner Vestager, European Commission.

## AI RELATED SENTIMENTS IN EUROPE

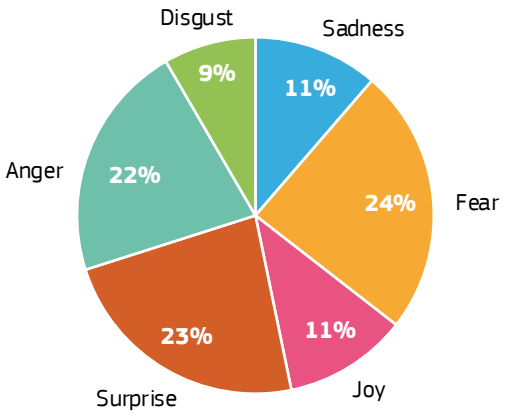
The European Media Monitor[1] examined online news related to Artificial Intelligence (AI) across the EU Member States over the last three months.

Reporting on AI corresponded to approx. **45,000 articles**, showing that this topic received rather moderate coverage when compared with the total news monitored for that period (> 10 million articles). The highest reporting volumes were in Germany, Italy and Spain[2].

While Austria and Italy have the most positive coverage, Bulgaria and the Czech Republic have the most negative coverage.

Fear, anger and surprise[3] dominate the spectrum of sentiments supporting the key challenge of building trust around AI. National differences were noted: the predominant emotion in articles from Belgium was fear, while for Germany and Italy surprise was more common.

**Figure: AI-related major sentiments across the EU**



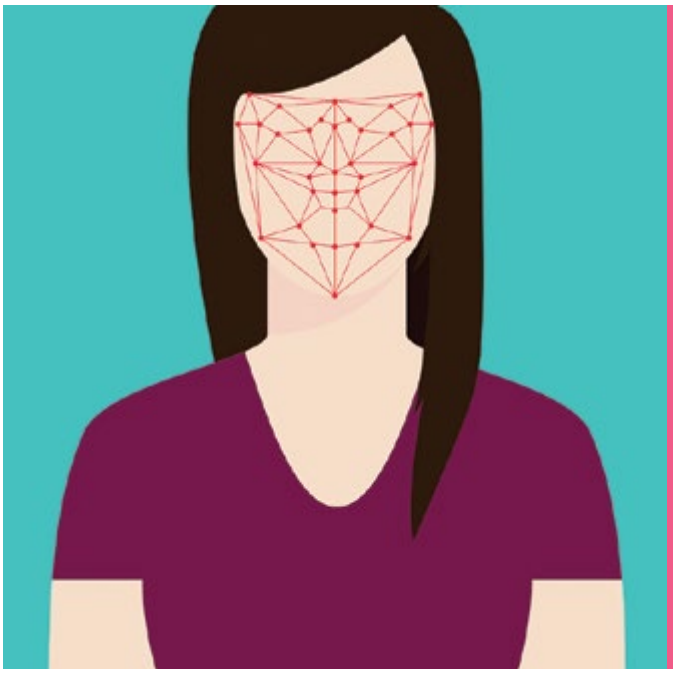

Source: EC JRC, ongoing research.

## AI POWERING HEALTH

Advancements in science and the use of AI could speed up drug discovery, make medicine more accessible and could make medicines more effective too.

- An AI system has identified a potential new medicine within 46 days. Based on **two AI techniques**[7] (called generative adversarial networks and reinforcement learning), the AI startup Insilico Medicine designed 30,000 molecules, synthesized six of them in the lab and tested the most promising - that showed characteristics of a medicine. This 'proof of concept' is exciting but we are still a long way from AI-designed drugs.
- **An important milestone**[6] for the role of machine-learning in medicine is a drug molecule invented completely by AI that is about to enter clinical trials for the first time. The medicine aims to treat obsessive-compulsive disorder and was developed by UK's AI start-up Exscientia in collaboration with the Japanese firm Sumitomo Dainippon Pharma.
- The convergence of AI with mass spectrometry[8], in particular highly sensitive glycoproteomics technology, could innovate cancer diagnostics through the identification of novel glycoprotein biomarkers that correspond to cancers (Intervenn Biosciences). A public software program uses machine learning and mass spectrometry datasets to distinguish between malignant and benign pelvic tumors, with the focus on early recognition of ovarian cancer.

***What if** media landscapes in the next four years get flooded with deepfake speeches of political leaders and this leaves no room for accurate judgements of what is factually said?*



## FACIAL AND EMOTION RECOGNITION - WHERE IS THE RED LINE?

Facial recognition to identify or verify a person's identity based on biometrics, is increasingly being used by both public and private entities. For example, it is used at airports in the US and China. In China it is also employed to monitor the attentiveness of pupils at school, or to 'tag' people on social media and to unlock smartphones.

Based on facial recognition, '**affect recognition technology**'[4] is gaining attention in job interviews, criminal suspect examinations (similar to lie detectors) and for setting insurance prices. It looks at micro-expressions i.e. what people say, how they say it and what expressions they make. Its value is around USD 20 billion.

**AI Now Institute**[5] calls for a ban of emotion recognition technology in hiring decisions and in pain assessment, because it is not accurate enough and leads to biases. It is known that these systems have fairness, accountability, transparency and ethical biases built into them, that amplify race and gender disparities.

1. JRC, European Media Monitor, 2020. Data available upon request
2. Coverage: Member States that use one of the following 14 languages: BG, CS, DE, EN, ES, FR, IT, NL, PL, PT, SK and AR, RU, TR
3. The predominant emotion expressed in news articles related to AI was determined using a machine-learning trained classifier.
4. BBC https://www.bbc.com/news/technology-50761116
5. AI Now Institute https://ainowinstitute.org/AI_Now_2019_Report.pdf
6. BBC https://www.bbc.com/news/technology-51315462
7. MIT Technology Review https://www.technologyreview.com/f/614251/an-ai-system-identified-a-potential-new-drug-in-just-46-days/
8. Business Wire https://www.businesswire.com/news/home/20191204005202/en/InterVenn-Biosciences-Releases-First-Ever-Software-AI-Enabled-Mass

## ENERGY CONSUMPTION TRENDS OF DIGITAL TECHNOLOGIES

Energy consumption by computing is growing at an unsustainable rate. For example, the Cambridge Bitcoin Electricity Consumption Index[1] (CBECI) estimates that the consumption of energy for mining bitcoins is equivalent to 68.11 TWh per year, which is higher than the annual consumption of Austria (64.60 TWh) and the Czech Republic (62.34 TWh).

Research from Aachen University estimates that by 2025, the energy consumed by German data centres powered by 5G will increase by 3.8 terawatt-hours (TWh) per year, equivalent to the electricity consumed by the 2.5 million people in Cologne, Dusseldorf and Dortmund[2]. The 2020 estimated global footprint of the tech sector is comparable to that of the aviation industry and larger than that of Japan, which is the world's fifth largest polluter[3]. Data centres make up 45% of this footprint (up from 33% in 2010), and network infrastructure 24%.

We are already moving towards the Internet of Transformation[4] (i.e. IoT 2.0). This will allow building hyperlocal/local/regional digital ecosystems, enabling innovative networking connectivity. In parallel, interaction strategies will limit data movement and distribute processing to the edge of the network. Low consumption technologies, such as edge computing[5] will reduce energy consumption.

**Figure:Countries active in energy efficient technologies**


Source: EC JRC, ongoing research

## AI TO POWER SMART GRIDS

AI can offer proactive intelligence to the smart grids. Self-learning algorithms can support grid operators on the decision-making in network control. AI can provide a direct connection between customers and the grid. It will play the role of taking into account the millions of variables and data points, such as weather, demand, location, generation assets, and proactively decide for every home where power will come from and how much it will cost. Making these decisions and learning from them makes AI suitable for smart grid implementation. For example, if the weather forecast says it will rain for three weeks, other production sources can proactively be scaled up to mitigate the loss in solar.

## SAVING BIODIVERSITY

Our planet is facing a massive extinction crisis. Many species are listed as endangered and it is predicted that 1 million species could become extinct in the coming decades[6]. Because AI enables fast processing of a number of signals, it can be used to identify risks and provide real-time alerts. For example:

- Invasive Alien Species: The popular citizen science application iNaturalist has developed an advanced computer vision model that has been trained to recognise over 5,000 species, using with 675,000 pictures of animals & plants. The model has been made publicly available. The JRC is currently experimenting with it and other models to improve early detection and management of invasive alien species in the EU[7].
- Penguin Watch, one of the most prominent examples of the crowdsourced research platform Zooniverse[8], is a citizen science project that captures pictures of penguin colonies in Antarctica. Penguins are threatened by climate change and human disturbances and this identifies changes in population. With the help of deep learning models, accurate counts of birds provide a better understanding of wildlife dynamics and threats to the ecosystem.
- Norway Royal Salmon[9] tries to improve fishing sustainability and safety using AI solutions based on remote object detection (from Microsoft and ABB). The system can monitor the salmon population. Underwater cameras capture images that are then analysed by AI for biomass and population estimation.

## PROTECTING THE RAINFOREST

Deforestation accounts for approximately 17% of all global carbon dioxide emissions and is considered to be the second largest contributor to carbon emissions. AI Sound Analysis can be used to protect the rainforest and help combat illegal logging through alerting the authorities (local rangers).

The system monitors 2.500sq km in 10 countries. Intentions are to scale it up to protect 25.000 km of forest in 5 years. The start-up estimates that one (sound recording) device in a tree can contribute to protecting three square km of rainforest[10].

1. Cambridge Bitcoin Electricity Consumption Index.https://www.cbeci.org
2. Aachen University, https://www.datacenterdynamics.com/en/news/5g-will-increase-energy-demands-data-centers-study-claims/
3. Belkhir and Elmeligi, 2018, Medium, https://medium.com/@AINowInstitute/ai-and-climate-change-how-theyre-connected-and-what-we-can-do-about-it-6aa8d0f5b32c
4. JRC. Data available on request
5. Quantum technologies use the properties of quantum effects – the interactions of molecules, atoms, and even smaller particles, known as quantum objects – to create practical applications in many different fields. https://ec.europa.eu/digital-single-market/en/quantum-technologies
6. https://www.biologicaldiversity.org/programs/biodiversity/elements_of_biodiversity/extinction_crisis/index.html
7. https://www.sciencedirect.com/science/article/pii/S0198971518302679
8. Oxford University, Penguin Watch project, https://www.zooniverse.org/projects/penguintom79/penguin-watch
9. The Record (2020), https://www.technologyrecord.com/Article/norway-royal-salmon-improves-sustainability-with-ai-101275
10. Rainforest Connection, https://rfcx.org

## CAN A PATENT BE GRANTED TO A MACHINE AND NOT A PERSON?

The European Patent Office[1] has issued a decision stating that an inventor must be a general person. They rejected two patent applications attributed to AI systems on the grounds that they do not meet the legal requirement of the European Patent Convention (EPC), namely that an inventor designated in the application has to be a human being and not a machine.

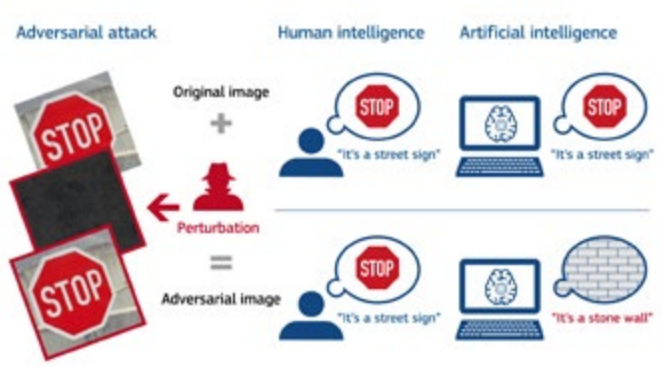
## TIME REQUIRED TO TRAIN A LARGE IMAGE CLASSIFICATION SYSTEM

In a year and a half, the time required[2] to train a large image classification system on cloud infrastructure has fallen from about three hours in October 2017, to about 88 seconds in July 2019. During the same period, the cost to train such a system has fallen similarly.

## ADVERSARIAL MACHINE LEARNING ATTACKS

The nature of machine learning (ML) algorithms makes them particularly sensitive to biases and unexpected behaviours. Deep learning (the latest generation of ML) relies on big datasets to find correlations and detect patterns that are then used to make predictions. They can exhibit non-linear and high-dimensionality relationships, resulting in difficulties to understand the logic behind the decisions taken by the algorithm. This can create opportunities for attacks.

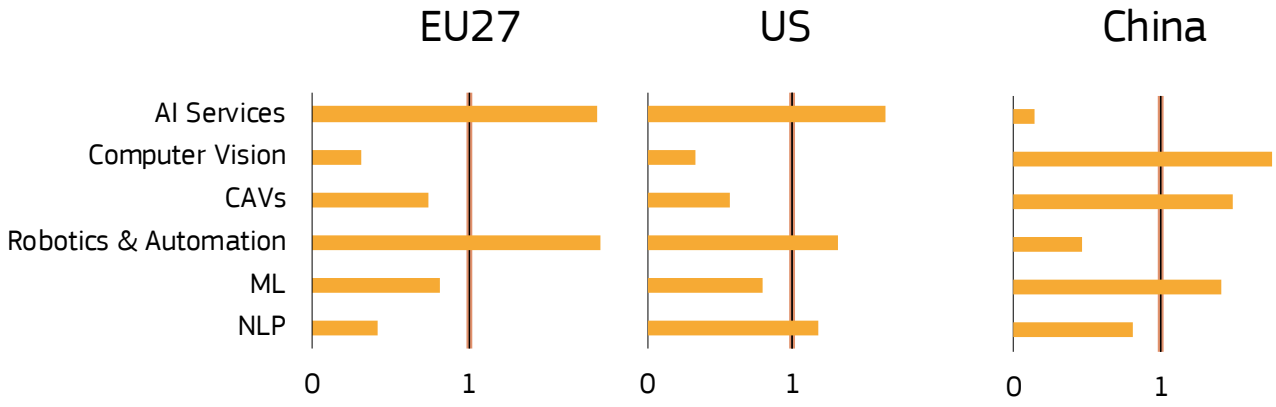
A prominent example of new vulnerabilities are adversarial machine learning attacks that may cause harm since they can affect the physical world. For example, they could be used to target automated vehicles, which could endanger passengers and pedestrians.




Such an attack consists of adding a specifically crafted perturbation to the image. To humans, the two pictures above look the same, but when the AI needs to classify them, the machine thinks that the one on top is indeed a stop sign, whilst the one below is classified as a wall.

***What if** an algorithm can accurately predict risks of premature death but a fraction of its results displays unconscious biases of the algorithm on specific social groups with direct consequences on their care?*

## AREAS OF SPECIALISATION




**Source: RC report "TES analysis of AI Worldwide Ecosystem in 2009-2018[3]**

Europe's profile shows a specialisation in activities in the areas of Robotics & Automation and AI Applications & Services[4], where it holds a comparative advantage over other world regions.
Europe produces *"more than a quarter of the world's industrial and professional service robots (e.g. for Precision Farming, security, health, logistics)"*, (International Federation of Robotics).
The excellence of European robotics research can be attributed to the allocation of 700€ million up to 2020, through the Robotics Public Private Partnership (SPARC, the partnership for robotics in Europe), and further private investments that reach 2.8€ billion in total (Accenture, 2018; National Strategy for Artificial Intelligence #AIFORALL, 2018).

The US is more active and specialised in the areas of AI Applications & Services, Robotics & Automation and Natural Language Processing. The US has a strong presence in almost all of the identified key AI areas.
China's interests are focused on the areas of Computer vision, Connected and Automated Vehicles (CAVs) and in the theoretical aspect of AI development (e.g. Machine Learning). The country is also substantially present in the thematic areas of Natural Language Processing and Robotics & Automation. In all the aforementioned areas (apart from machine learning), China is among the top three global venture capital investors, i.e. in unmanned vehicles (CAVs and drones), robotics and virtual reality (Pinho, 2019; Ke and de Diego).

1. European Patent Office (2020), https://www.epo.org/news-issues/news/2020/20200128.html
2. AI Index Report (2019), https://hai.stanford.edu/sites/g/files/sbiybj10986/f/ai_index_2019_report.pdf
3. Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
4. Services such as database access, software, visualisation, etc., allowing the deployment and maintenance of applications. These applications cover a variety of needs in a cloud, the web, or in local machines (e.g. for financial advice, travel planning, business decisions, cloud storage services, Virtual Private Network (VPN) clients etc.).

## JRC mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

Any questions? Contact us here:
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European Commission

# FORESIGHT ON CRITICAL RAW MATERIALS FOR EUROPEAN INDUSTRY

Issue 2, March 2020

Joint research centre

## WHY A FORESIGHT NEWSLETTER?

The objectives of the newsletter "FORESIGHT ON" are to raise awareness and stimulate debate on trends, important emerging issues and potential implications, as well as to support future thinking (timeline 3-10 years) among policymakers, to trigger reactions and inspire strategies and long-term policies. The primary audience is the College of Commissioners and the senior management of Directorates-General.

This foresight newsletter looks forward at key challenges and opportunities that future European policies on Critical Raw Materials might need to address. The intention of the newsletter is to enlarge the discussions by highlighting forward-looking questions backed by recent facts and figures, related to Critical Raw Materials. The objective is not to be comprehensive but to shed light on relevant issues for European policymaking.

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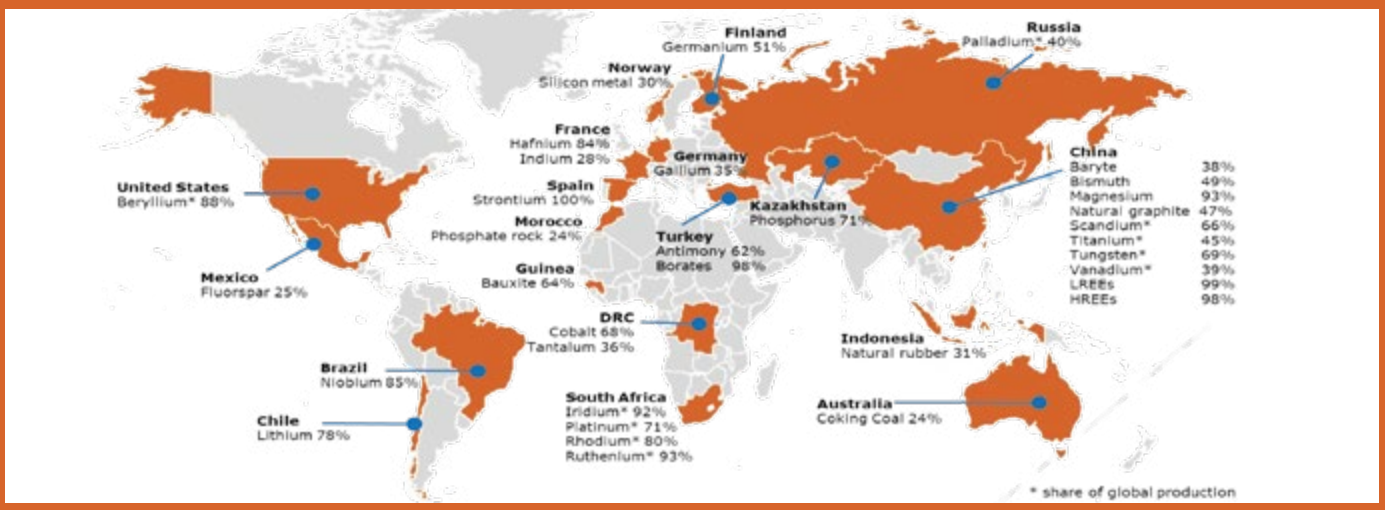
## CRITICAL RAW MATERIALS IN EUROPE: WHERE DO THEY COME FROM?[1]




**The EU relies almost completely on third countries (i.e. those outside the EU) for the sourcing of critical raw materials (CRMs) essential to lead the twin ecological and digital transitions and foster the competitiveness of our economy[2].** They form a strong industrial base, producing a broad range of goods and applications used in everyday life and include modern technologies ranging from batteries and electronics, to clean energy and defence. The import dependency is particularly high for rare earth elements, magnesium, borates, niobium, lithium and cobalt.

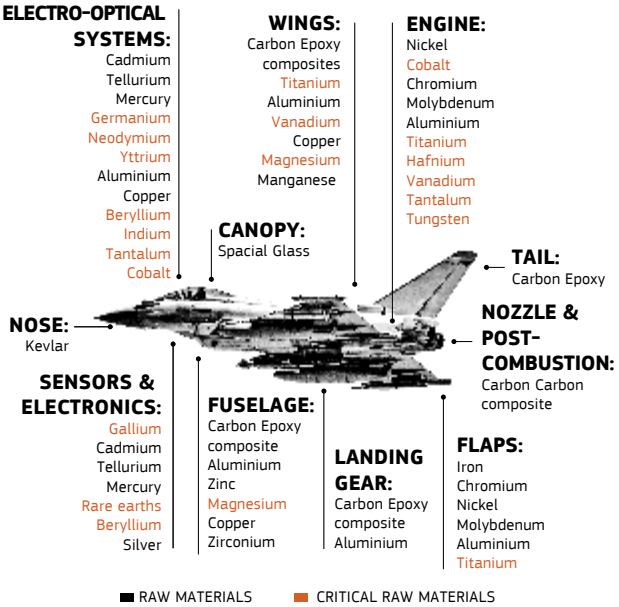
The EU's dependency on raw materials makes it vulnerable to supply disruptions. Significant **EU vulnerabilities also exist in processing, recycling, refining and separation capacities** to such an extent that certain materials mined in Europe have to go elsewhere, e.g. to China, for further processing before being shipped back.

High dependency **calls for greater resilience and diversification of supply,** notably by making better use of EU domestic sourcing, the circularity of raw materials and our strategic trade policy and economic diplomacy.

## EU DEFENCE AND RAW MATERIALS

All industries, including the European defence industrial base, require very specialised high-performance processed materials[3] for the production of defence applications. The raw materials come from China (58%), Chile (8%), South Africa (8%), the US (2%) and other countries (24%). The defence industry relies 100% on imports from countries outside of the EU for about half of them.

**Figure: Raw material used in EU Defence**




Source: EC JRC, ongoing research.

## GLOBAL PARTNERSHIPS ON CRMs

New global partnerships are key to diversifying sourcing of CRM. China has rapidly expanded both mining and refining capacity and rights in Africa. The US and Japan are diversifying sourcing away from China. In February 2020, the US Geological Survey[4] developed a new methodology to identify which mineral commodities they rely on and which are at risk of supply disruptions. These commodities are vital for mobile devices, renewable energy, aerospace and defence.

Japan is working to reduce its reliance on China for rare earth elements to under 50% by 2025, through initiatives[5]. Japan also plans to revise legislation to allow its company Japan Oil, Gas and Metals National Corp (JOGMEC) to invest in rare earth smelting projects. JOGMEC could ensure Japan's stable access to cobalt through these investments and counter China's securing rights in the Congo. The Trilateral EU-US-Japan Conference on Critical Materials launched in 2011 is a positive example of the EU's action on the global scene. They publish lists of CRMs and meet annually to exchange information and to identify areas for cooperation to reduce risks. The EU published its latest assessment in 2020.

## GREENLAND'S POTENTIAL

It is estimated that Greenland could have 39 million tonnes of rare earth oxides[6]. By way of comparison, total reserves for the rest of the world stand at 120 million tonnes. The highest resource potentials are for beryllium, fluorspar, graphite, niobium and rare earths. Some areas carry a high potential to host undiscovered mineral deposits[7]. The critical bottlenecks for Europe are yet further downstream on the value chain[8].

1. https://secure.ipex.eu/IPEXL-WEB/dossier/document/COM20200474.do
2. European Commission, Study on the EU's List of Critical Raw Materials (2020), Publications Office of the European Union, Luxembourg, 2020
3. European Commission, Critical materials for strategic technologies and sectors in the EU — A foresight study, Publications Office of the European Union, Luxembourg, 2020
4. US Geological Survey, https://www.usgs.gov/news/new-methodology-identifies-mineral-commodities-whose-supply-disruption-poses-greatest-risk-us?qt-news_science_products=1#qt-news_science_products
5. Nikkei Asian Review, https://asia.nikkei.com/Politics/International-relations/Japan-to-pour-investment-into-non-China-rare-earth-projects
6. Centre for Minerals and Materials, http://mima.geus.dk/wp-content/uploads/MiMa-rapport-2016_3_Critial-Minerals-in-Greenland_med_omslag.pdf
7. Financial times, 2019, https://www.ft.com/content/f418bb86-bdb2-11e9-89e2-41e555e96722
8. EIT RawMaterials, Towards a European Rare Earth Alliance, 2020

## CORONAVIRUS – WHEN MULTIPLE RISKS INTERSECT

As we are currently experiencing in the face of the COVID-19 outbreak, global supply chains are particularly vulnerable to disruption. As COVID-19 spreads, there is no 'just in time' deliveries possible. We saw a similar pattern on the Japanese (and Asian) economies following the 2011 tsunami.

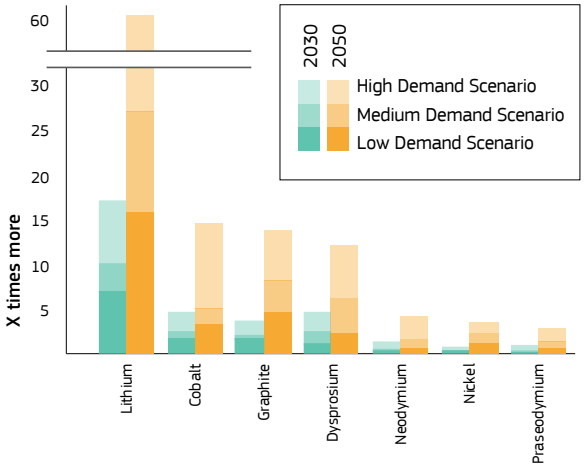
For example, China is the world's largest exporter of rare earths, controlling >90% of global supply. Disruptions due to the outbreak of COVID-19 are particularly relevant, as earths are at the beginning of strategic products of high technological content and high added value, such as batteries, ICT and military applications. The sector is currently operating at 20% capacity and strategic reserves may be able to cover demand (decreased considerably), for two weeks only. As the spread of the coronavirus unfolds, Fiat Chrysler Autos, Renault, BMW and Peugeot are set to shut down some of their production, after an electronics factory in Lombardy (MTA) was forced to close down by the Italian authorities. Fiat Chrysler Auto has also halted operations at its Serbian facility because of a shortage of components from China, following logistic bottlenecks due to reduced capacity at container terminals. Volkswagen's production at factories in China is also affected and there are growing concerns of additional supply chain disruptions that could affect manufacturing in EU plants.

The short-term consequence of the disruption is less demand and temporarily lower prices for raw materials. The industrial metals price index[1] shows a 7.1% drop since the arrival of coronavirus risks: it includes price setbacks of 10.4% for copper and 8.7% for nickel. This amounts to long-term risk, as investments in the necessary capacity required to fulfil future demand are affected.

The COVID-19 outbreak therefore highlights vulnerabilities in the current global supply chain model, especially where major EU industry, like the automotive sector, is over-reliant on a small number of third country suppliers of raw & processed materials. Many electronic producers have also warned of a shortfall[2] in this quarter's sales targets, because of their reliance on China for chips and other products[3].

## FUTURE EU DEMAND FOR STRATEGIC SECTORS AND TECHNOLOGIES

**Figure: Additional EU raw material consumption for low carbon technologies in 2030 and 2050**




**Source: EC, ongoing research**

Delivering the twin climate and digital transition as well as 'a stronger Europe' priority depends on the availability of sustainable and responsibly-sourced raw materials. The JRC modelled and converted climate targets for 2030 and 2050 into the annual raw material demand needed to produce all the necessary electric vehicles, motors, energy storage and wind plus solar power. The analysis indicates that for the three key sectors, i.e. renewable energy, e-mobility, and defence and space, the EU would need 3 times more cobalt and 10 times more lithium for the baseline climate scenario by 2030 and respectively 5 times more cobalt and 27 times more lithium by the year 2050. Under a high demand scenario, representative of an accelerated uptake of low-carbon strategies and low material substitution, this could go up to 15 times more cobalt in 2050 and almost 60 times more lithium compared to EU consumption in 2018. Demand for rare earths used in permanent magnets, e.g. for electric vehicles, robots or wind generators, could increase tenfold compared to the current supply to the whole EU economy[5].

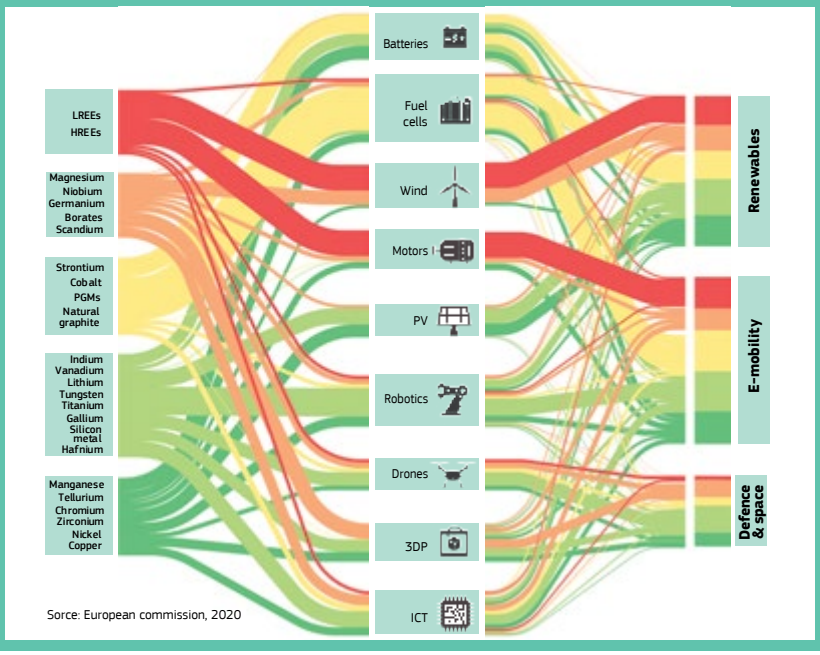
## CRMs: THE RACE IS ON

Increasing competition between sectors[6] for the same raw materials, processed materials and components is expected. This applies for example, to borates, gallium, indium, rare earths, cobalt, niobium and silicon metal in renewable energy, e-mobility and the defence & space industries.

As the mineral commodities are traded on internationally, highly intransparent and inefficient markets, and as other key countries (such as the US & China) are reliant on imports for some of them (e.g. for niobium, chromium, tantalum), their availability for the EU might become even more challenging.

As a result of the transition towards a low-carbon, digital economy and new industrial strategies, competition between world regions for access to raw materials will become even more acute.

**Figure: CRMs in Strategic Sectors**




Sorce: European commission, 2020

1. https://foreignpolicy.com/2020/02/18/coronavirus-economic-impact-worldwide-supply-chain-disruptions/
2. Moody's Analytics, https://www.moodys.com/researchdocumentcontentpage.aspx?docid=PBC_1212580
3. Some examples: https://www.nasdaq.com/articles/philips-says-coronavirus-outbreak-will-impact-q1-financial-results-2020-02-25 - https://www.reuters.com/article/us-china-health-apple-suppliers-analysis/if-apple-is-hurting-due-to-the-coronavirus-its-suppliers-and-rivals-likely-are-too-idUSKBN20C147
4. https://www.reuters.com/article/us-fiat-chrysler-china/fiat-chrysler-halts-production-in-serbia-over-china-disruption-idUSKBN2081UN
5. European Commission, Critical materials for strategic technologies and sectors in the EU — A foresight study, Publications Office of the European Union, Luxembourg, 2020

## DUE DILIGENCE FOR HUMAN RIGHTS AND RESPONSIBLE SOURCING

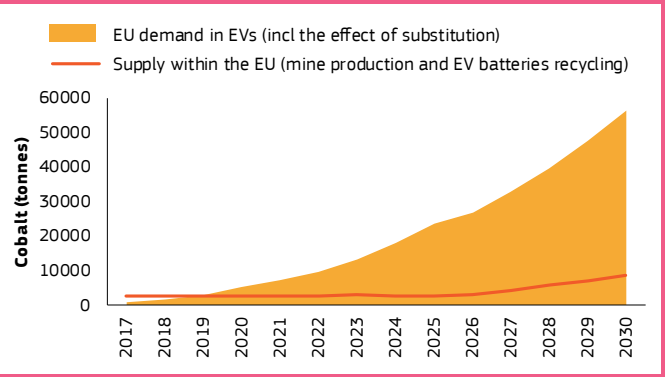
From 1 January 2021, as stated in the Conflict Minerals Regulation[1], due diligence[2] will become a legal obligation in the EU for companies importing tin, tungsten, tantalum and gold ('3TG)' from high-risk and conflict-affected areas.

**The EU will prepare a new legal framework for batteries that will provide for a responsible sourcing of raw materials needed for the production of batteries in the context of the circular economy for the European market by October 2020.** It will apply to sourcing of cobalt that has been one of the most problematic raw materials, as well as others. The Democratic Republic of the Congo provides more than 60% of global supplies of cobalt.

Human rights abuses, child labour and life threatening working conditions have been reported in the DRC[3]. The two largest cobalt-mining sites in the DRC, produce one third of the world's total volume and have entirely Canadian and Chinese shareholders. Almost half of the refining of cobalt takes place in China, but the EU has a sizeable share of around 20% as well.

The gap between cobalt supply and demand is expected to increase by 2030. **The global and European expansion of the electric vehicle market will exponentially increase demand for cobalt in the next decade.** The EU domestic supply provides only 15% of EU demand for e-mobility, mainly from refining in Finland. Europe will increasingly be dependent for its future demand on circularity and imports. At a global level, around 64 000 tonnes of cobalt production will be needed annually by 2030, on top of the mining capacity increases that are already planned.

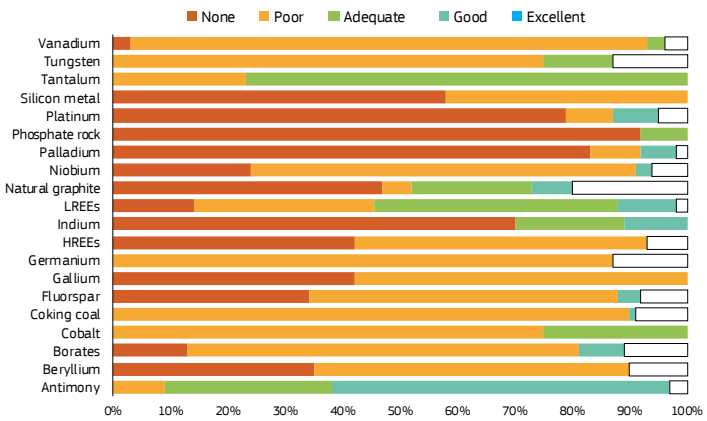
**Figure: Future EU supply – demand balances for cobalt**




Source: JRC Science for Policy Report, 2018

## SEEKING ALTERNATIVES TO CRMs

**Figure: Substitution potential of CRMs in various applications**




Source: SCRREEN project, 2019

Substitution of CRMs[4] with less critical raw materials is one mitigation strategy. Together with recycling, substitution is included as a risk-reducing factor in the criticality assessment calculations. The search for substitutes is driven by better performance and lower cost too. Although known substitutes can help mitigate criticality, experience suggests that the expectations of this strategy should not be overestimated, as substitutes rarely provide an equivalent function.

Due to their unique properties, some CRMS e.g. phosphate rock, platinum and palladium, indium and silicon metal have no viable substitute for most of their current applications.

## NEW MINING PROJECTS IN THE EU

Mobilising Europe's domestic potential is one of the key elements to increasing strategic autonomy. Domestic raw materials help reduce material dependencies and provide materials sourced with high social and environmental standards. Furthermore, the raw materials industry creates jobs in the EU. While the EU's extraction industries employ about 650 000 people (that is multiplied along the value chain) the EU's manufacturing sector dependent on raw materials accounts for 25 million jobs.

However, Europe's resources and CRMs are underused. This is notably due to a lack of investment, diverse and lengthy permit procedures, and low levels of public acceptance. To unlock domestic potential Europe needs a predictable regulatory framework, simplified procedures (e.g. one-stop-shop) and open dialogue with all stakeholders at local levels, as well as a greater awareness of raw materials.

**NUMBER OF ACTIVE EXPLORATION AND NEW MINE DEVELOPMENT PROJECTS FOR BATTERY RAW MATERIALS**

| | Cobalt | Lithium | Nickel |
|---|---|---|---|
| EU | 6 | 7 | 239 |
| Global | 362 | 303 | 4900 |
| EU share | 4% | 5% | 5% |

Source: JRC ongoing work, background data from S&P Global

1. EU Regulation (EU) 2017/821 of the European Parliament and of the Council of 17 May 2017 laying down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected and high-risk areas. 2017.
2. Due diligence is how a business understands, manages and communicates about risk. This includes the risks it generates for others, and the risks it encounters through its strategic and operational decisions and actions. https://ec.europa.eu/growth/sectors/raw-materials/due-diligence-ready/explained_en
3. E.g. Amnesty International, 2016. This is what we die for: Human Rights Abuses in the Democratic Republic of the Congo Power the Global Trade in Cobalt.
4. SCRREEN project, http://scrreen.eu/

## COPERNICUS FOR RAW MATERIALS

Earth observation (EO) data, made available by Copernicus, represents a real asset for a sustainable mining life cycle: exploration; extraction; closure and post-closure. Several initiatives for exploration, environmental and safety monitoring of extraction and mining waste disposal and others have already shown its potential. Copernicus could potentially allow us to observe artisanal and small scale mining operations and to identify environmental damage via satellite imaging.

An ongoing study of the European Space Agency is exploring the current and future applications of EO in the mining industry and anticipating the future development of EO sensors, systems and services.

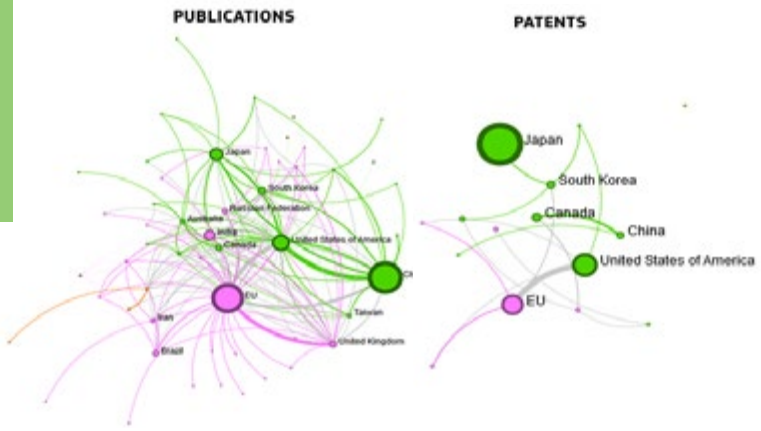
## RAISING AWARENESS OF CRM RECOVERY AND SUSTAINABLE SOURCING

Every year 9.9 million tonnes of waste electrical and electronic equipment (WEEE) is generated in the EU. Around 30% of it is collected and recycled. The recovery of CRMs from WEEE is currently below 1%. To contribute to the recovery of CRMs, it is important to raise consumer awareness[1] from an early age, through campaigns on the importance of collection and recycling of WEEE. This would allow their continued circulation within the European market and increase the contribution of secondary raw materials to overall supply. A European project with trials in four different countries has shown that the introduction of incentives for product donation by producers, such as free data erasure of mobile phones and computers, would increase the rate of collection and improve the potential recovery of CRMs.

## THE EU IN THE INNOVATION LANDSCAPE

Globally, the EU is second in the production of scientific publications about the recycling and recovery of CRMs – after China - but ahead of the US and Japan. Within the EU, Germany, France and Italy lead in the number of published articles. With regards to the number of patents (applied for in more than three jurisdictions), the EU is third, after Japan and the US. Germany, France and Finland have the highest number of patents[2] within the EU.

**Figure: Publications and patents on recycling or recovery of CRMs**




Source: EC JRC, ongoing research.

## THE CIRCULAR ECONOMY


EIT, 2019[3]

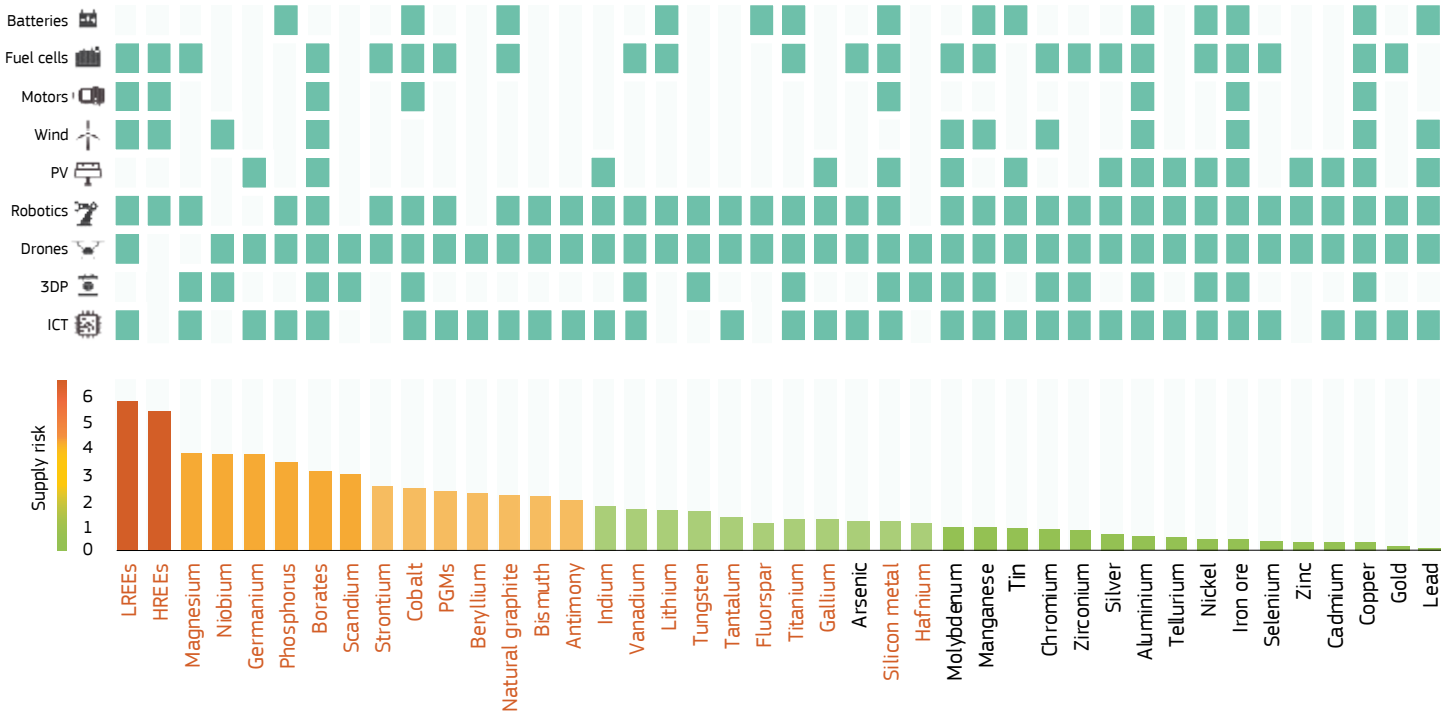
Circularity of metals and recycling of raw materials from low carbon technologies is an integral part of the low carbon economy. The EU is at the forefront of the circular economy and increasing the use of secondary raw materials. For example, more than 50% of metals such as iron, zinc and platinum are recycled and they cover more than 25% of EU consumption.

Still **for many others, especially those needed in renewable energy or high tech applications, such as rare earths, gallium, or indium, secondary production represents only a marginal contribution of less than 5%.** Significant amounts of resources leave Europe in the form of waste and scrap, which are potentially recyclable into secondary raw materials.

The EU needs to establish a robust and integrated EU market for secondary raw materials, and more research in reprocessing waste. Furthermore, extractive and processing industries need to become more resource-efficient, sustainable and circular.

1. Critical Raw Material Recovery, http://www.criticalrawmaterialrecovery.eu
2. EC JRC, TIM ongoing research
3. https://eitrawmaterials.eu/

## SUPPLY RISK OF RAW MATERIALS FOR KEY TECHNOLOGIES




**European commission, 2020**

The EU is highly dependent on third countries[1] outside of the EU for raw materials for its strategic value chains, such as fuel cells, batteries, solar and wind energy, robotics, 3D printing, drones and digital technologies.

**Fuel cells:** The fuel cell industry relies heavily on platinum-based catalysts. South Africa is by far the largest producer of platinum in the world.

**Wind and traction motors:** The EU only provides 1% of the raw materials for wind energy. Major concerns exist about the supply of rare earths for the production of permanent magnets for both wind turbine generators, as well as for traction motors for EVs.

**Solar energy:** The EU's contribution is marginal in each step of the supply chain. The EU only provides 1% of silicon-based Photo Voltaics (PV).

**Robotics:** The EU produces only 2% of raw materials, with China the major supplier again with 52%. In the global market, the EU is a major player in robotic assemblies with 41% of global supply.

**3D Printing (3DP)** relies on high performance alloys, cobalt, hafnium, niobium, scandium, silicon metal, tungsten and vanadium. China provides 35% of the raw materials, while the EU only provides 9%.

**Drones:** China delivers more than one third of the raw materials and dominates civil drone production, while the US and Israel dominate military drone production.

**Digital Technologies** consume a particularly high share of elements such as copper, gallium, germanium, gold, indium, PGMs, rare earths and tantalum. Europe is largely dependent on imports of high-tech components and assemblies in all supply chain stages.

## RAW MATERIAL FOR FUTURE BATTERIES

China, Africa and Latin America provide 74% of all battery-related raw materials currently, and China alone produces 66% of lithium-ion batteries.

The EU provides less than 1% of lithium-ion batteries. To create a secure, sustainable and competitive value chain for batteries in Europe, the European Commission - with the support of EIT InnoEnergy - has set up the industry-led European Battery Alliance (EBA). The EBA brings together over 260 industrial and innovation actors, and has managed to channel consolidated private investments of up to EUR 100 billion into flagship manufacturing projects, covering the whole value chain, from raw materials to battery cells to production and recycling.

The EBA Business Investment Platform is currently mobilising EUR 2.2 billion in financing for major EU projects in lithium mining, processing and recycling (in Spain, Portugal, the Czech Republic, Germany and Finland). These projects should lead to a production of 150,000 tons of lithium per year by 2025, which would effectively cover 80% of the forecasted demand surge for batteries in Europe.

1. European Commission, Critical materials for strategic technologies and sectors in the EU — A foresight study, Publications Office of the European Union, Luxembourg, 2020
2. For more information, including the market inputs, stocks and waste battery amounts generated, see the JRC – Raw Materials Information System (RMIS): https://rmis.jrc.ec.europa.eu/apps/bvc/#/

## JRC mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

Any questions? Contact us here:
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European Commission

# FORESIGHT ON SECURITY

Issue 3, July 2020

Joint research centre

## WHY A FORESIGHT NEWSLETTER?

The objectives of the newsletter "FORESIGHT ON" are to raise awareness and stimulate debate on trends, important emerging issues and potential implications, as well as to support future thinking (timeline 3-10 years) among policymakers, to trigger reactions and inspire strategies and long-term policies. The primary audience is the College of Commissioners and the senior management of Directorates-General.

This edition of the newsletter focuses on Security, defined broadly, and has been produced ahead of the launch of the Security Union Strategy. It, however, goes beyond the scope of the strategy. The intention of the newsletter is to enlarge the discussions by highlighting forward-looking questions backed by recent facts and figures, pertaining to the Security policy area. The objective is not to be comprehensive but to shed light on relevant issues for European policymaking.

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We acknowledge the feedback and comments from the SG and policy DGs.

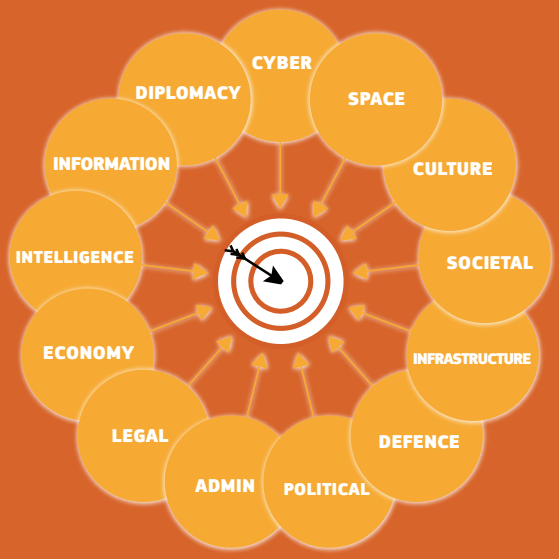
## THE CHANGING NATURE OF CONFLICT

The events of 2014 in Ukraine were a clear example of how an actor can seek strategic objectives with low-level conflict. Compromise of critical infrastructure and cyber-attacks, just to name a few, were key elements of this hybrid campaign, combined with a denial of action and low-level armed conflict.

Other global actors are increasing their footprint around the globe using hybrid tools, mainly in the economic and social domains, such as foreign direct investment, influence and interference activities, as well as disinformation campaigns. Similarly, disinformation has been one of the tools used against Europe during the COVID-19 crisis[1].

Actors embarking on hybrid attacks can achieve highly strategic multiple objectives such as undermining public trust in democratic institutions, challenging the core values of societies, gaining geopolitical influence and power and affecting political leaders' decision-making capability. The EU and its Member States need to develop a whole-of-society strategy to address hybrid threats and bolster resilience.

**Figure: Hybrid Threats might influence all areas of a state's domains of power**

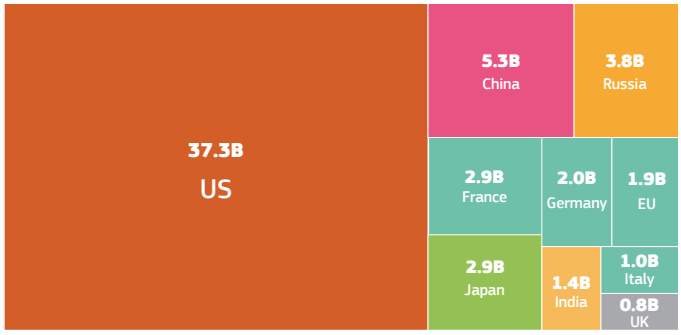



Source: EC JRC, 2020

## SPACE: A GLOBAL COMMON OF STRATEGIC IMPORTANCE

The global space economy is worth €320 billion and is expected to rise to €1 trillion by 2040[2]. It provides over 230 000 jobs in the EU and contributes between €46 to €54 billion to the EU economy[3]. Satellite-based data is of strategic importance, needed for positioning, navigation, timing, global monitoring, control, intelligence, broadcasting and communication. Space assets and access to space services are increasingly under threat[6].

**Figure: Government space investment (in billions EUR)**




Source: Fortune, 2018

**EU space investment reached €1.9 billion in 2018, but when individual Member State investments are added (about €7 billion) it outpaces China and is second to the US.** The US is traditionally the leader in space investment (€37.3 billion in 2018[4]), but China is investing heavily in space to develop a space-based economy[5] and has increased public investment by 359% over the last 15 years (€5.3 billion in 2018). In June 2020, China launched its final 'Beidu' satellite, thus completing its own global navigation system.

## SOVEREIGNTY IN THE CYBERSPACE

**The US, Russia and China are rapidly strengthening their cyber-strategies.** To reflect the growth in cyber threats[7] one of the key concepts of the US strategy is that of 'defending forward', i.e. to "*disrupt or halt malicious cyber activity at its source*". In practice this means that the strategy takes a proactive approach focussing not only on preparedness to address attacks when they occur, but rather to stifle them at their source.

The defence sector is also taking a more prominent role to protect defence-related critical infrastructures, which are critical for military operations, and engages with the private sector for this purpose. In 2019, Russia legislated to isolate the Russian segment of the internet from the rest of the web – allegedly with the use of a parallel 'national DNS infrastructure'. The so-called 'Runet' will thus remain operational in the advent of a foreign cyber-attack. Such a practice breaks the decentralised architecture of the Internet and leads to the creation of Internet islands where access can be monitored and controlled by the State.

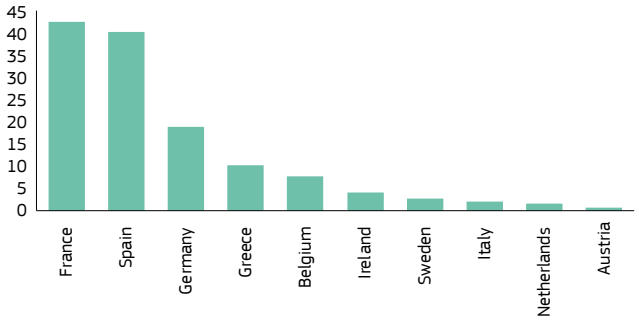
Such developments highlight that the **internet infrastructure and governance will be a major challenge for the EU in the future.** For example, the 'New IP' proposal by China is persistently promoted by Huawei and the Chinese Government within the framework of the ITU (International Telecommunication Union). It goes directly against the Internet fundamental values of openness and transparency and foresees a top-down architecture managed by a central governmental authority. An important question for the future will be how to combine sovereignty in cyberspace with globalised connectivity.

1. The Joint Communication on Tackling COVID-19 Disinformation shows clearly the importance of this threat for the EU.
2. Morgan Stanley, https://www.morganstanley.com/Themes/global-space-economy
3. https://ec.europa.eu/growth/sectors/space_en
4. https://fortune.com/longform/space-program-spending-by-country/
5. https://thediplomat.com/2019/02/chinas-get-rich-space-program/
6. Space Threat Assessment 2020, Centre for Strategic and International studies.
7. JRC Cybersecurity flagship report

## COSTLY CONSEQUENCES OF CYBER CRIME

Cybercrime is expected to cost the world €5.5 trillion by the end of 2020, up from €2.7 trillion in 2015, due in part to the exploitation of the COVID-19 pandemic by cyber criminals[1]. This represents the greatest transfer of economic wealth in history and will be **more profitable than the global trade of all major illegal drugs combined,** reducing incentives for innovation and investment. In addition, during the period 2004-2016, terrorism has cost the EU-27 plus UK approx. €185 billion in lost GDP[2].

**Figure: Cost of terrorism by country from 2004-2016 (in billions EUR)**




Source: European Parliament[3]

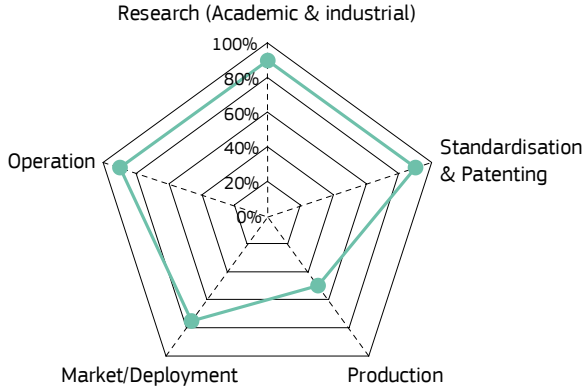
## 5G AND EU OPEN STRATEGIC AUTONOMY

5G technology will soon be the cornerstone of critical infrastructures and services, such as energy, health, transportation, telecommunications and industry 4.0. Hence, technological sovereignty in this domain is paramount for national security.

As of March 2020, 10 European countries have deployed commercial 5G infrastructures[4]. Ericsson expects the global market size of 5G to surpass €1.1 trillion within 10 years, with more than 150 million 5G connected devices in less than 12 months following network launch. Bloomberg says that "*about one billion people worldwide are likely to be 5G-enabled within five years, which would lead to €11 trillion in global economic output by the mid-2030s*"[5].

**In the 5G value chain, the EU performs well in research (academic and industrial) and standardisation, but lacks capabilities in the production of equipment.** Leveraging this research performance to establish European global champions would enable the EU to both achieve technological sovereignty and reap the benefits of a fast-growing market. This practice would also allow the EU to improve its security particularly in relation to critical components of infrastructures.

**Figure: Areas of EU's strengths in 5G**




Source: EC JRC

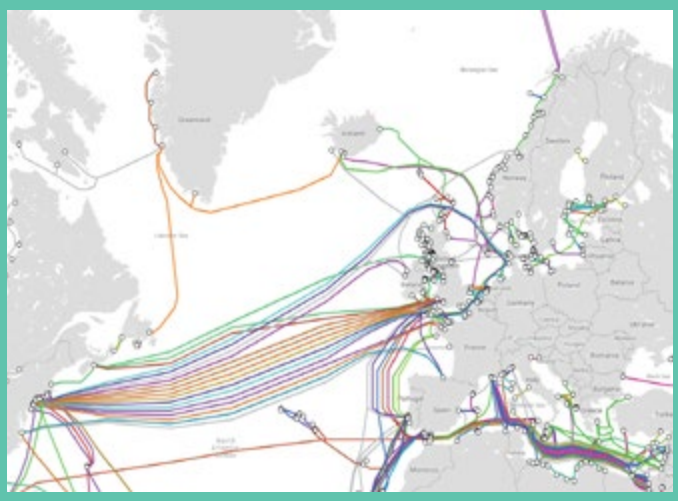
## RESILIENCE OF CRITICAL INFRASTRUCTURES

Critical infrastructures (such as energy systems, transportation and telecommunications) are essential for daily activity in society. The COVID-19 crisis has shown that disruptions of critical infrastructure can have massive cascading impacts on society and the economy. For example, air traffic restrictions due to travel restrictions, or closing of borders alone can result in hundreds of billions of lost Euros[6]. The COVID-19 crisis also exposed the vulnerabilities of the health infrastructure.

Although the EU's economy depends heavily on critical infrastructures, in many cases EU Member States do not have full control over them. Some infrastructures are located in third countries. For example, 99% of international data traffic passes through submarine cables connecting the globe[7]. Another example of dependency of the EU-27 is energy imports; more than 50% of primary energy available in the EU is imported from non-member countries[8] (solid fossil fuels, natural gas, oil and petroleum products).

The number of man-made threats and their sophistication with relatively cheap technological means (i.e. drones[9]) is increasing, along with the number and intensity of natural hazards. **This requires a need for a mindset shift focusing on resilience and continuity of services, rather than full protection of physical assets against all possible threats and hazards.** Investment in: systems' redundancy (e.g. submarine cable infrastructure where even if one cable is cut, the traffic can be redirected to another one); rapid response teams; diversification of critical supply sources; resource efficiency; domestic production/infrastructure; and addressing systemic risks, are key for more resilient infrastructures and a more resilient economy.

**Figure: The global submarine cable infrastructure**



Source: TeleGeography

1. Cybersecurity Ventures, "The 2019 Official Annual Cybercrime Report," Herjavec Group
2. European Parliament, The fight against terrorism: Cost of Non-Europe Report, 2018: https://www.europarl.europa.eu/RegData/etudes/STUD/2018/621817/EPRS_STU(2018)621817_EN.pdf
3. Ibidem.
4. European 5G observatory
5. JRC Cybersecurity Flagship report
6. https://www.sciencedirect.com/science/article/pii/S0925753520301880
7. Newsweek, 2015. https://www.newsweek.com/undersea-cables-transport-99-percent-international-communications-319072
8. Eurostat: https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_production_and_imports
9. In 2018 hundreds of flights were cancelled at Gatwick airport due to unauthorised drone flights in the vicinity of the airport with obvious economic consequences.

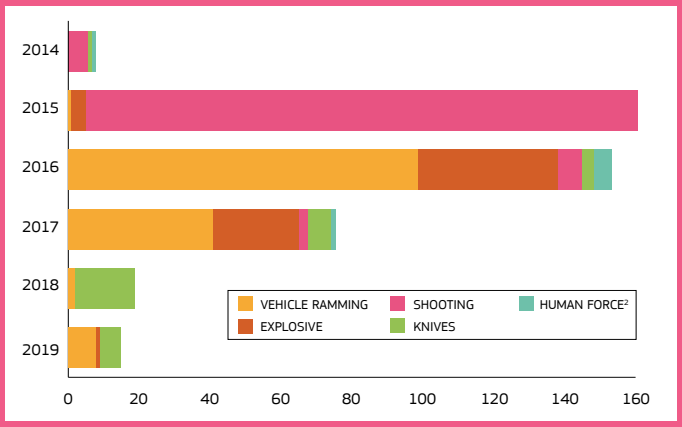
## TERRORISM THREATENING PUBLIC SPACES

**The average EU citizen ranks terrorism fifth on their list of concerns** according to a 2019 Eurobarometer survey[1], although deaths from terrorist attacks rank at the bottom of the respective statistics for causes of death. However, terrorist attacks can change citizens' perception of security.

The terrorist attacks in Paris, Nice and Barcelona targeted public spaces using new methods, such as aiming a motor vehicle at a target with the intent to inflict fatal injuries. Terrorist attacks using more traditional means, such as explosives, are still a real threat, in particular in controlled areas like airports. Explosives' trace detection (ETD) equipment is an important component of screening processes at EU airports. Recently, drones were used for disrupting civil aviation operations in busy airports in Europe, causing significant economic impact due to flight cancellations. There are fears that this 'off-the-shelf', cheap and easily accessible technology could be used for chemical attacks, or attacks with explosive devices at mass public events.

The guiding principle to the protection of public spaces is prevention rather than reaction. For example, Artificial Intelligence (AI) can mine texts from open-media sources to discern the *modus operandi* of attacks occurring in other parts of the world, to grasp trends from discussions on new methods of terror, as well as to analyse public sentiments on controversial topics, which may promote radicalisation.

**Figure: EU Casualties from terrorist attacks by year and method**




Source: EC JRC.

## PREVENTING CHILD SEXUAL ABUSE

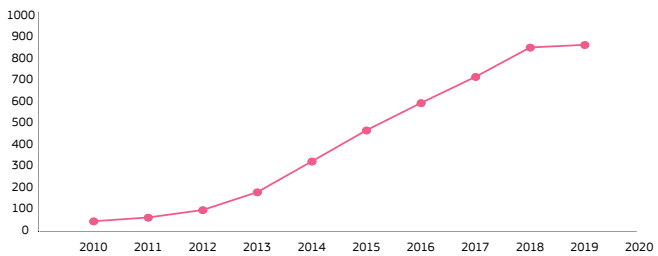
**In the last ten years, online child sexual abuse has increased exponentially worldwide, from one million reports of child sexual abuse material in 2010 to 17 million in 2019[3]**, with 800 000 coming from Europe alone. In 2019, almost nine in ten known URLs containing child sexual abuse material were hosted in Europe. This compares to eight in ten in 2018[4]. Sexual abuse and sexual exploitation of children constitute major violations of fundamental rights and in particular of children's rights to protection and care necessary for their well-being, as stated in the UN Convention on the Rights of the Child.

A recent study[5] highlights the need to better endorse the idea of **preventive support** to counter child sexual abuse. Awareness-raising campaigns, support to victims, research, building networks of experts gathering best practices, developing a framework of policies and appropriate funding would serve to tackle the crime of child sexual abuse.

## CYBERSECURITY – A SOCIETAL MUST

Cyber-attacks can simultaneously impact a huge number of people (e.g. 3 billion Yahoo accounts hacked in 2017, 77 million users of Sony PS3 in 2011, 1.3 million and 250 000 citizens respectively in the cases of Estonia and Ukraine).

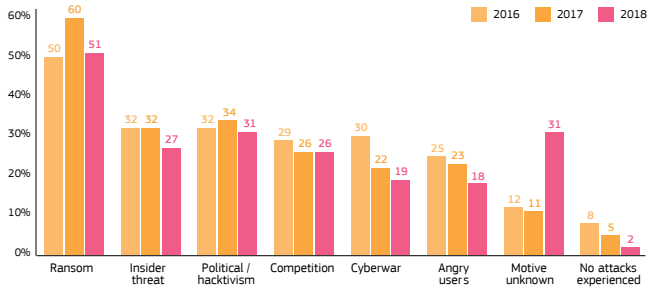
**Figure: Malware evolution from 2010 to 2019**




Source:AV-TEST

The number of registered malware (software designed to harm) globally has increased 20 fold in the last decade[6]. Given that data flow and information is the lifeblood of digital society, cybersecurity is essential to ensure that digital services work securely, while guaranteeing citizens' privacy and data protection. **Therefore, cybersecurity has evolved from a technological option to a societal must.** The challenge for policymakers is to identify how actions in these areas will contribute to a new 'European cyber-secure society by design'.

**Figure: Overview of motivations identified behind cyber-attacks**




Source: Radware. Note: The data come from an annual survey by Radware of 790 organisations of various types. The percentage indicates the share of respondents who were victims of a cyber-attack.

## SECURITY BY DESIGN: TOWARDS A PARADIGM SHIFT?

Security by design[7] will be more prominent in the future, including comprehensive security considerations from the planning and design stages of public spaces and infrastructure. It will go hand-in-hand with considerations of aesthetics, liveability, use, safety and maintenance. **Applying security by design to both physical and cyber-space reduces the cost of security measures, makes them more effective and avoids disturbing community life**.

1. https://ec.europa.eu/commfrontoffice/publicopinion/index.cfm/survey/getsurveydetail/instruments/standard/surveyky/2253
2. human force= Physical violence and/or use of apparatus not classified as weapons (i.e. axes).
3. Speech by Commissioner Johansson at a webinar on "Preventing and combating child sexual abuse & exploitation: towards an EU response", 9 June 2020
4. Internet Watch Foundation, https://www.iwf.org.uk/report/iwf-2019-annual-report-zero-tolerance
5. Fighting child sexual abuse: prevention policies for offenders – Inception Report, EUR 29344 EN, doi:10.2760/48791. https://op.europa.eu/en/publication-detail/-/publication/8ecaa7e4-c77f-11e8-9424-01aa75ed71a1/language-en
6. Cybersecurity our Digital Anchor, EUR30276
7. Security considerations and measures are taken into account during the conceptualisation and design of a new infrastructure. In the cyber domain, this practice is extensively used in software engineering.

## INCREASING ENVIRONMENTAL VULNERABILITIES

**27% of the world's countries are likely to face catastrophic water stress by 2050** (i.e. insufficient resources for their needs) and 22% catastrophic food stress. Today, more than two billion people live in countries experiencing high water stress and about four billion experience severe water scarcity for at least one month per year. Water scarcity is a strong and increasing catalyst for conflict. Climate hazards and extreme weather conditions are exacerbating the problem. 2.26 billion people worldwide are estimated to live in areas with high or very high exposure to climate hazards, of which 1.24 billion, in 40 countries, have low levels of peace already[1].

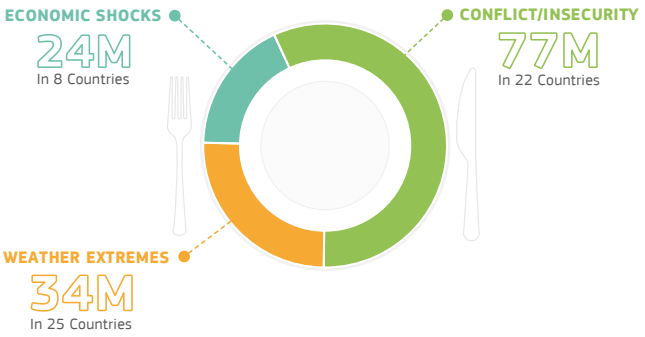
**At least 40% of the intra-state conflict between 1950 and 2010 were linked to natural resources, such as minerals, timber, oil, or livelihood resources, such as water and fertile land[2].** Environmental security is increasingly dominating national and international agendas, shifting defence and geopolitical paradigms.

## COVID-19: FOOD CRISES EXPECTED TO WORSEN

**In 2019, 135 million people in 55 countries were in a food crisis (in addition to the 821 million suffering from chronic undernutrition)[3].** Food crises lead to internal displacement, international migration, as well as hunger and other things.

In 2020, the situation is likely to worsen given the economic impact of the COVID-19 crisis. Conflict and insecurity are the main drivers of food crises, though economic shocks and extreme weather are also very important drivers.

**Figure: Drivers affecting food security (M=million)**




Source: 2020 Global Report on Food Crises

## BLACK SWANS AND GRAY RHINOS

***A Black Swan is a low-probability event which has potentially immense consequences. A Gray Rhino is a highly probable event with huge potential impact, but nevertheless largely neglected.***

As an example of a Black Swan, recall the 2010 eruptions of the Eyjafjallajökull volcano in Iceland which caused unprecedented chaos to aviation across Europe. About 20 European countries closed their airspace and more than 10 million passengers were affected. Such extreme events can wreak havoc to modern critical infrastructures which provide essential services. Another example is solar flares, which can create huge problems for telecommunication systems, satellites, electricity systems and aviation. According to certain studies[6] an extreme solar event could lead to electricity grid damage that would require several years for a full recovery. It is not possible to protect our systems and infrastructures against all natural hazards.

**Whether COVID-19 was a Black Swan or a Gray Rhino is currently under much debate. Nevertheless, the response should be to invest in resilience, both at the technological and societal level.** More resilient systems and societies can withstand and absorb the shock, minimise consequences and "bounce forward" quickly to full functionality and, if possible, adapt, transform and perform better after the shock. For example, Chile and New Zealand quickly recovered from earthquakes in 2010 and 2011, respectively, due to their resilient systems and societies, while Haiti still struggles to overcome the destructive effect of earthquake of 2010[7].

## NEW SEA ROUTE WITH MANY IMPLICATIONS

**Climate change has led to the opening of the Arctic Sea Routes, thus reducing the time that a ship needs to travel between Asia and Europe.** This will have huge environmental, geopolitical and economic implications. The use of heavy fuel oil in the maritime transport sector further accelerates ice caps melting, according to a number of studies[4]. At the same time, the rise of temperatures in the Arctic leads to permafrost thawing, which is likely to be a 'tipping point': the release of huge amounts of methane into the atmosphere will accelerate global warming.

This new sea route is estimated to lead to a reduction in transportation costs, as well as a reduction of the number of ships crossing the Suez channel, which will have obvious geopolitical consequences. Roughly 8% of world trade is currently transported through the Suez Canal and this share could drop by around two-thirds with a re-routing of trade over the shorter Arctic route[5]. The Northern Sea Route is furthermore inside Russia's Exclusive Economic Zone. Among many potential implications, this could also affect the Belt and Road Initiative.

**Figure: New transport routes in the arctic**


Source: Melting Ice Caps and the Economic Impact of Opening the Northern Sea Route, Eddy Bekkers, Joseph F. Francois, and Hugo Rojas-Romagosa

1. Global Peace Index 2020, Institute for Economics and Peace; http://visionofhumanity.org/app/uploads/2020/06/GPI_2020_web.pdf
2. https://www.visionofhumanity.org/wp-content/uploads/2020/10/GPI_2020_web.pdf
3. 2020 Global Report on Food Crises: https://www.wfp.org/publications/2020-global-report-food-crises
4. https://www.climatechangenews.com/2018/04/09/arctic-countries-call-regional-heavy-fuel-oil-ban-un-shipping-talks/
5. Eddy Bekkers, Joseph F. Francois, Hugo Rojas-Romagosa, Melting Ice Caps and the Economic Impact of the Opening of the Northern Sea Route, CPB Discussion paper 307
6. National Research Council of the National Academies (2008) Severe space weather events—understanding societal and economic impacts—Workshop Report. The National Academies Press, Washington DC, p 79 Available at https://www.nap.edu/catalog/12507/severe-space-weather-events-understanding-societal-and-economic-impacts-a
7. Resilience – Overcoming natural disasters, Munich RE, https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/resilience/resilience-overcoming-natural-disasters.html

## FROM INTERNET TO THE INTERNET OF THINGS

In 2018 there were 17 billion connected devices globally, 7 billion of which were Internet of Things devices[1-2]. The latter number is expected to grow to more than 13 billion by 2022, thereby overtaking the number of non-Internet of Things-connected devices worldwide. Similar projections[3] estimate 25 billion connected things by 2021.

**Poor cybersecurity in such devices could lead to a compromise in their performance, or that they become weapons in the hands of malicious actors for deploying massive Distributed Denial of Service Attacks.** Privacy is an additional concern, sensitive personal data may be at risk if efficient cybersecurity measures are not imposed.

The COVID-19 pandemic has further magnified the critical nature of cybersecurity in our society. The sudden massive move to teleworking, online schooling and the use of digital services in hospitals, laboratories and government services has enlarged 'the attack surface' for malicious actors. Against this, education and awareness of citizens is fundamental.

## BIOMETRIC TECH AGAINST CHILD-TRAFFICKING

Europol's 2018 report on 'Criminal Networks involved in the trafficking and exploitation of underage victims in the European Union'[4] has confirmed that:

- One in every four minor victims in the EU is below 11 years.
- Traffickers often seize minor victims' documents and give them fake identities to conceal their real age and facilitate their transport into the EU.
- Minor victims and traffickers hold fraudulent tourist visas obtained from EU consulates in source countries.

Biometric technologies and in particular fingerprint recognition, can be effective in the fight against human trafficking. **Recent scientific developments indicate that fingerprint is effective also for children identification[5].** This is why the European Visa Information System (VIS) lowered the fingerprinting age from 12 to 6 years, in support of the fight against trafficking and exploitation of underage victims.

## CRIMINALS LEVERAGING ADVANCED TECH

EncroChat, an encrypted phone network used by criminals, was dismantled following an investigation by the French and Dutch Law enforcements, Europol[6] and Eurojust.[7] Millions of messages sent to plan crimes have been analysed and this has enabled a large numbers of arrests (in France, UK, Sweden, Norway and >100 in the Netherlands).

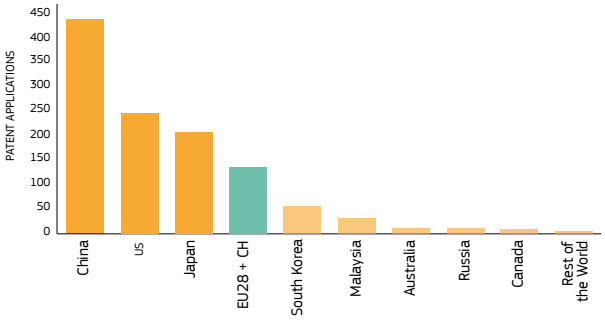
The operation shed light on the global connectivity of criminal networks, cooperating using advanced technologies: EncroChat guaranteed anonymity (e.g. no SIM card association) and discretion both of the encrypted interface (undetectable) and the terminal (e.g. removal of the camera, microphone and GPS). It also exemplifies how end-to-end secure communication poses a substantial challenge for law enforcers calling for new tools, methods and adequate safeguards.

## QUANTUM COMPUTERS, COMMUNICATIONS AND SENSORS

Quantum computers might break the cryptographic systems that are the backbone of cybersecurity, including e-commerce. Some experts believe that they might be able to break common cryptographic protocols by 2032[8]. Defence against this vulnerability can be achieved by distributing keys for encrypting and decrypting data. Quantum key distribution requires a dedicated quantum communications infrastructure.

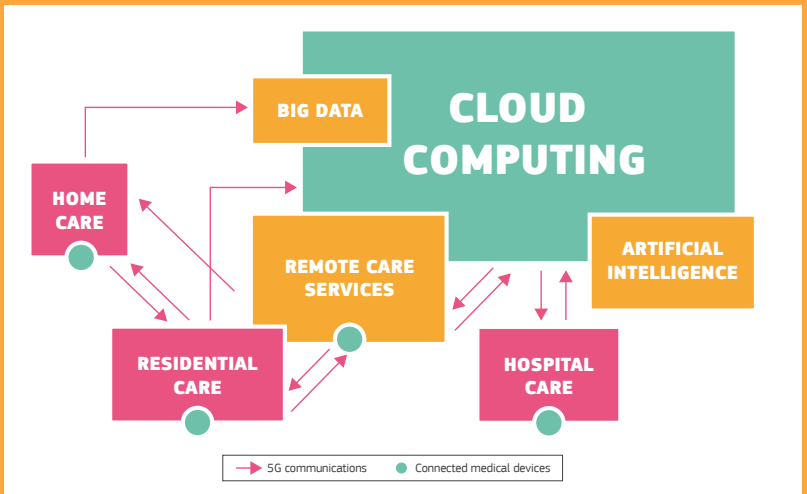
The EU is now actively studying how to build one using fibre links on the ground and ESA satellites. **Although Europe has very strong research capabilities in quantum technology, it is outpaced in patent applications by China, the US and Japan.** Nevertheless, the EU is striving to remain competitive with its Quantum Technology Flagship programme.

**Figure: Quantum technology patents per country[9]**




Source: EC JRC 2019

## CYBERSECURITY AS AN ENABLER FOR HEALTH DIGITALISATION




**COVID-19 has confirmed that the future of healthcare will revolve around big data and smart medical devices connected to the internet. This makes cybersecurity imperative.** Science, the Internet of Things, AI and data will all contribute to the better detection of diseases and enable disease prevention and personalised treatment. **Such innovation may be called the Internet of Medical Things.** New actors, such as remote healthcare services, are already emerging and the overall trend will be a shift from hospital care towards home care, making cybersecurity of medical devices even more crucial and urgent.

**Figure: E-health - the new frontier of cybersecurity**
Source: EC JRC

1. The Internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
2. Knud Lasse Lueth, 2018
3. Omale, 2018
4. https://www.europol.europa.eu/publications-documents/criminal-networks-involved-in-trafficking-and-exploitation-of-underage-victims-in-eu
5. https://ec.europa.eu/jrc/en/publication/automatic-fingerprint-recognition-children-elderly-ageing-and-age-effects
6. https://www.europol.europa.eu/newsroom/news/dismantling-of-encrypted-network-sends-shockwaves-through-organised-crime-groups-across-europe
7. http://www.eurojust.europa.eu/press/PressReleases/Pages/2020/2020-07-02a.aspx
8. Experts surveyed by the JRC estimated this on average
9. https://ec.europa.eu/jrc/en/publication/patent-analysis-selected-quantum-technologies

## JRC mission

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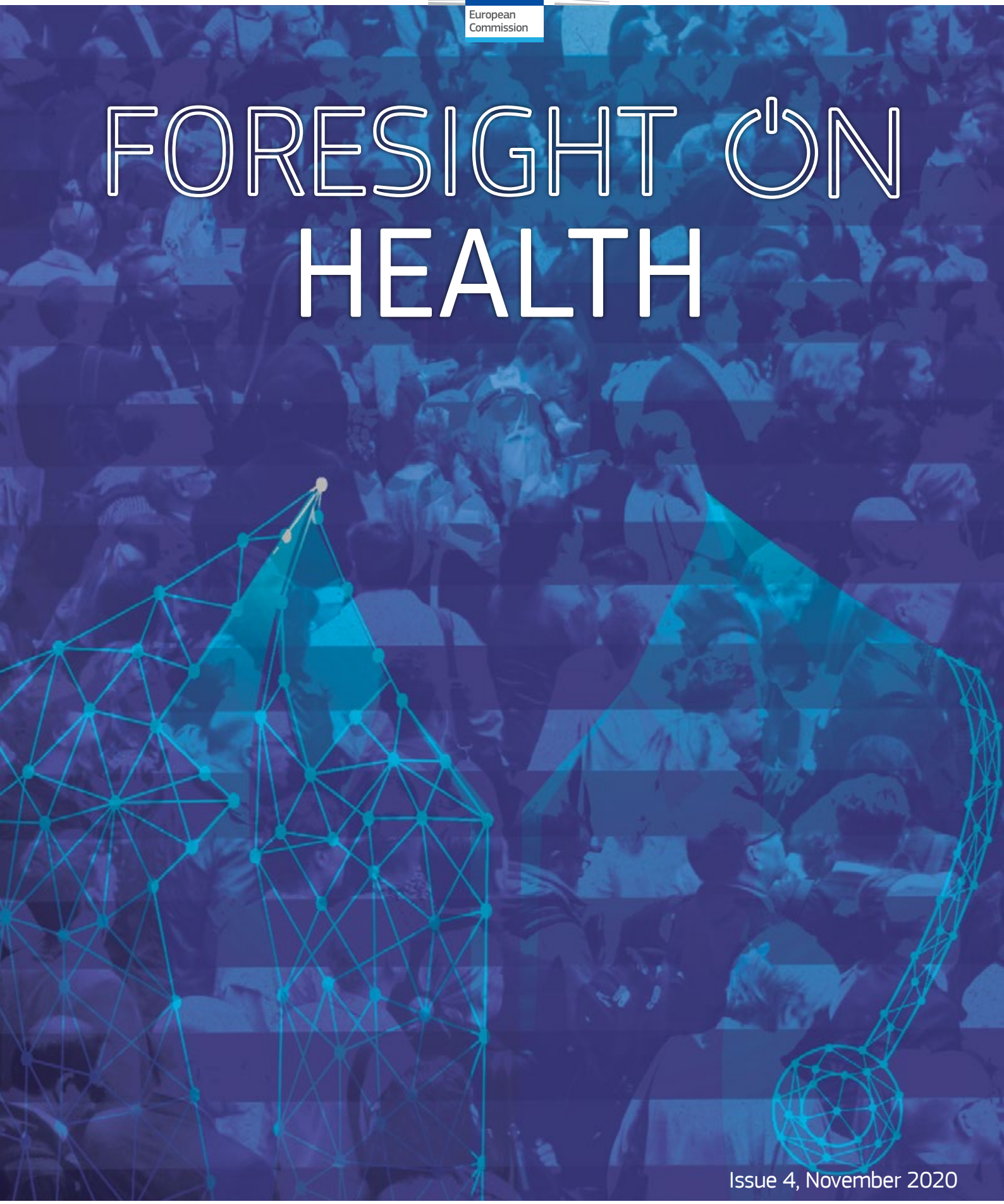
Any questions? Contact us here:
**JRC-foresight@ec.europa.eu**



European Commission

# FORESIGHT ON HEALTH



Issue 4, November 2020

Joint research centre

## WHY A FORESIGHT NEWSLETTER?

The objectives of the newsletter "FORESIGHT ON" are to raise awareness and stimulate debate on trends, important emerging issues and potential implications, as well as to support future thinking (timeline 3-10 years) among policymakers, to trigger reactions and inspire strategies and long-term policies. The primary audience is the College of Commissioners and the senior management of Directorates-General.

This foresight newsletter looks forward at key challenges and opportunities that a future European health union might need to address. The intention of the newsletter is to enlarge the discussions by highlighting forward-looking questions backed by recent facts and figures, related to Health policy. The objective is not to be comprehensive but to shed light on relevant issues for European policymaking.

Cover image:
Ryoji Iwata - Unsplash.com
Tex vector - Adobestock

Other images:
*The unsuspected me – my microbiome:*
Centers for Disease Control and Prevention (CDC) - Unsplash

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We acknowledge the feedback and comments from the SG and policy DGs.

## VACCINE NATIONALISM

The competition between countries and companies to be the first to discover and acquire COVID-19 vaccines could trigger an unequal distribution of COVID-19 vaccines globally.[1] Russia has approved its first vaccine in August and claims that it (Sputnik V) is 92% effective.[2] China has vaccinated 100,000 people.[3] Venezuela is planning a mass immunization campaign with the Russian and Chinese vaccines.[4]

The optimal strategy against COVID-19 globally will be an equal access to vaccines and a coordinated deployment.[5] The possible allocation of COVID-19 vaccines world-wide shows discrepancies between high-income countries with vaccine coverage for 250% of their population and low-income countries with vaccine coverage only for 14%. Modelling shows that if developing countries do not get access to vaccines, the EU could lose EUR 40 billion per year of GDP.[6]

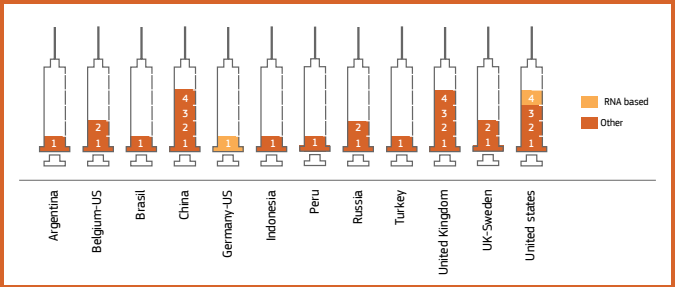
If national and economic interests alone drive nations' vacci- nation strategies, it could lead to unfair and narrow-minded competitive advantages. This risks making vaccines a geopolitical instrument. The World Health Organisation (WHO) Director General has warned that vaccine nationalism will prolong the pandemic, not shorten it.[7]

The EU is part of WHO Access to COVID-19 Tools Accelerator (ACT)[8], which facilitates vaccine access for low-income countries.

The EU has provided financial support for COVID-19 research and treatments through the Coronavirus Global Response pledging marathon, with EUR 9.7 billion raised. (The US and China have pri- oritized other initiatives). But despite major EU investment, few of the top 10 most advanced vaccine studies involve EU medical companies. However, one of the first mRNA-based vaccines that shows results above 90% efficiency is European (German/American from BioNTech-Pfizer, currently in Phase III of development).

Securing access to health technologies is of strategic importance for Europe for current and future health crises.

**Figure: Vaccine Clinical trials in phase III**




Source: WHO (accessed on 20 Nov 2020)

## SHORTAGE OF MEDICINES

Medicine shortages in the EU have increased 20-fold[9] since 2000. The COVID-19 pandemic provoked a surge in demand for critical medicines and medical device supplies and has uncovered vulnerabilities in supply chains. It has also raised questions about the necessity of certain critical manufacturing capacity in the EU. While Active Pharmaceutical Ingredients (APIs) for innovative products under the patent period are produced in Europe, most of the APIs for generic medicines are sourced from India and China. Even when APIs are produced locally, most of their raw materials are sourced from China.[10]

In recent years, there has been a clear trend of outsourcing APIs by big pharmaceutical multinationals for cost-efficiency reasons. However, this creates vulnerabilities that are especially visible in a crisis – such as that demonstrated by Paracetamol, which has not been produced in the EU since 2004 and which resulted in a lack of supplies during the first wave of COVID-19.[11] Widely used antibiotics (amoxicillin), painkillers (aspirin and paracetamol), as well as vaccines against hepatitis B and even life-sustaining drugs to treat cancer (busulfan and zolendric acid) are all regularly at risk of shortages.

There are two trends reversing this. First, Chinese and Indian authorities are increasingly aiming for a higher commitment from domestic API manufacturers towards environmental and safety measures. This results in higher costs and delays in getting products ready for the market. Second, some multinational pharmaceutical companies have reviewed their global supply chains and have moved the production of APIs back to Europe. This contributes to reducing dependencies, ensures a more reliable quality of API sourcing and brings better preparedness in case of a future health crisis.

## HEALTH DATA OWNERSHIP

Health data ownership is emerging as a key frontline in the global race to control the increasing amount of sensitive personal information stored in data clouds.[12]

IT platforms could store data about vaccines, medicines safety and contribute to more efficient regulatory science. They could also be used to increase resilience to emerging health threats by providing an early warning system, contact tracing and surveillance. Health data is used to develop new proprietary technologies and the application of Artificial Intelligence has huge potential to provide new diagnostics, treatments and better care, including predicting an individual's risk for diseases (though ethical and privacy risks remain). The increase of cybercrime directed at health cloud services and the cloud market growth expectations (from EUR 42 billion in 2019, to almost EUR 250 billion in 202713) highlight its importance. Sharing of health data is vital for any EU strategy towards protection, prevention, preparedness and response to cross-border health threats.

One of the priorities of the Digital Single Market is to enable citizens to securely access and share their health data across borders through an interoperable European Electronic Health Record system. However, most cloud services are controlled by foreign providers.14 The European Health Data Space and Gaia-X project are examples of initiatives to create EU data platforms. EU Health Data Space will ensure citizens' control over their own personal data - which is fundamental for gaining users' trust, promoting technology uptake and safeguarding the information.

Health data ownership is fundamental for EU strategic autono-my. Initiatives to reduce the EU's dependency and protect EU citizens' control over their own data warrants a strategic approach.

1. https://globalchallenges.ch/issue/special_1/the-vaccine-race-will-public-health-prevail-over-geopolitics/
2. https://wonderfulengineering.com/russias-sputnik-v-covid-19-vaccine-is-also-90-effective-russian-authorities-claim/
3. https://www.vox.com/2020/9/11/21431416/coronavirus-vaccine-china-sinopharm-sinovac-emergency-authorization
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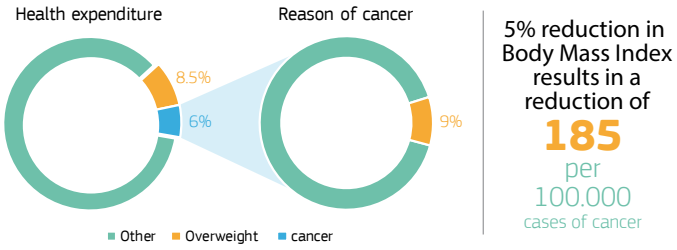
5. https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-33-vaccine/
6. https://www.rand.org/randeurope/research/projects/cost-of-covid19-vaccine-nationalism.html
7. https://www.dw.com/en/paris-peace-forum-to-raise-more-than-500-million-for-global-coronavirus-vaccine-access/a-55577629
8. https://www.who.int/initiatives/act-accelerator
9. https://www.europarl.europa.eu/news/en/headlines/society/20200709ST083006/medicine-shortages-in-the-eu-causes-and-solutions
10. https://ec.europa.eu/health/sites/health/files/files/committee/ev_20200312_795_en.pdf
11. https://www.chemistanddruggist.co.uk/news/covid-pharmacies-report-difficulty-sourcing-paracetamol
12. https://www.politico.eu/article/health-data-global-ai-fight/
13. https://www.fortunebusinessinsights.com/cloud-storage-market-102773
14. https://www.weforum.org/agenda/2020/01/future-of-artificial-intelligence-healthcare-delivery/

## PREVENTING CANCER AND OBESITY

Cancer risk factors include ageing, genetics, lifestyle and ex- posure to environmental factors. It is estimated that in 2020, 2.7 million new cancer cases will be diagnosed in EU-27 countries and 1.3 million cancer deaths will occur[1]. The number of new cases is estimated to grow by 3.2 million per year by 2040.[2]

**Figure: European health expenditure and reason of cancer**




Source: OECD and BMJ Open

Obesity is another concern. There is more to obesity than overeating: causes include diseases, genetics, life style and life circumstances. In 34 out of 36 OECD member countries, more than half of the population is overweight and 8.5% of health expenditure is spent on treating obesity and the related diseases it brings.[3,4] Obesity accounts for 70% of the treatment costs for diabetes, 23% for cardiovascular diseases, and 9% for cancer.

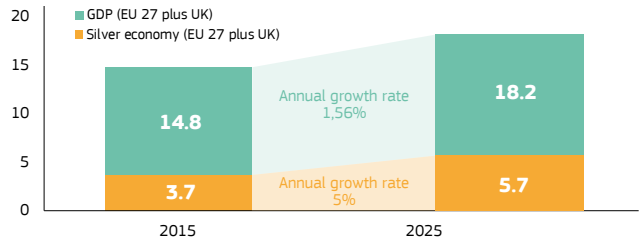
Trends show that this large economic burden is rising, but it could be lowered by applying preventive measures and new therapies. For example, according to projections, >1 million cases of chronic disease per year could be avoided with just a 20% reduction in calories of our diet.[5] Similarly, about 40% of cancers are preventable by modifying habits and life style. Furthermore, application of personalised vaccines (RNA-based), cell therapy, gene editing and microbiome treatments to cancer promise great efficacy. The venture capital and investment in tumour treatments have been steadily increasing since 2015.[6]

## AGEING POPULATION, A BURDEN OR AN OPPORTUNITY?

Long-term demographic projections reveal that Europe is increasingly 'turning grey'. The total population of EU-27 plus UK is projected to rise from 511 million in 2016 to 520 million by 2070, but its working-age population (aged 15 to 64) will significantly drop, from 333 million in 2016 to 292 million in 2070, due to birth rate, life expectancy, and migration flow dynamics.[7] This will place a clear economic burden on society, as the old-age dependency ratio in the EU (i.e. people aged 65+ versus 15-64) is projected to almost double, from 29.6% in 2016 to 51.2% in 2070. It means that for every person aged 65+, there will be less than two working-age people in 2070, as opposed to over three now. The average EU health expenditure for people over 65 today accounts for 6.7% of GDP and is increasing. Estimates for 2070 reach 8.0% of GDP. We are living more years, but with less abilities due to ageing.

The 'silver economy' (i.e. the economy of the population over 50[8]) of fers opportunities to contribute >EUR 5.7 trillion to the EU economy by 2025. Health is a major issue for the silver economy, especially the fields of prevention of disease, and allowing seniors to be autonomous and in good health for as long as possible.[9] Technological innovations such as home automation, Artificial Intelligence, Internet of Things, or eHealth, are leading to more personalised elderly care, but these are likely to not be available for all. Telemedicine is also key to helping elderly patients, especially in a public health crisis like COVID-19 and as a way to increase capacity when hospitals are full.

**Figure: Size of silver economy compared to EU GDP (in Trillions EUR)**




Source: European Commission[10]

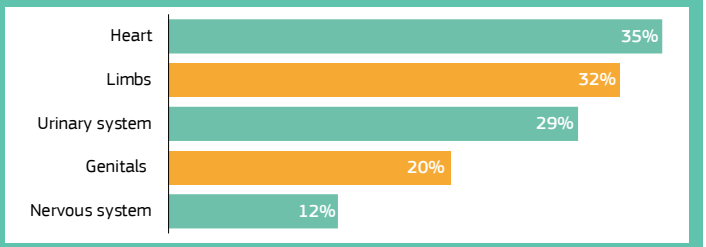
## RARE DISEASES – A SPRINGBOARD FOR FUTURE DEVELOPMENTS IN PERSONALISED MEDICINE

In Europe today, 6-8%[11] of the population is affected by a 'rare disease'10 (27-36 million)[12]. Rare disease treatments have challenges, but find- ing solutions has proven to be a surprising spring board for future developments in personalised medicine.

Successful treatment development depends on incentives and good data. Member States have an economic incentive to find cures and reduce health costs[13], but due to the low numbers of patients spread across the EU, there are few economic incentives for the pharmaceutical companies to develop new therapies. Clinical trials are necessary to define efficiency and toxicology of any medicine. Low numbers of patients make it difficult to recruit for trials and increase the cost and time necessary for drug development. This enhances the need for collaboration. To overcome this barrier, pooling of patient's data among member states is crucial. The EU's strategic objective for rare diseases is to improve patient access to diagnosis, information and care, and to assist in the pooling of resources. Data sharing is now facilitated by the EU Platform on Rare Diseases.[14]

Alongside the economic and therapeutic advantages of collaboration, a hidden advantage of investing in rare diseases, is that many are associated with mutations in a single gene. This makes them good candidates (model systems) for the application of new technologies (gene thera- pies, recombinant proteins). Recently, companies such as RareMark and Healk (UK-based) are applying genome sequencing and artificial intelligence tools to speed up diagnosis and the identification of the best drug candidates. At the same time, these specific technologies pave the way for future developments in personalised medicine.

**Figure: Most common congenital anomalies rare diseases**




Source: EC JRC

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2. https://www.who.int/csr/don/en/
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7. https://ec.europa.eu/info/sites/info/files/economy-finance/ip079_en.pdf
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10. European Commission, The Silver Economy – Final report, ISBN 978-92-79-76911-5, doi:10.2759/64093
11. A disease affecting less than 5 in 10,000 people
12. COUNCIL RECOMMENDATION of 8 June 2009 on an action in the field of rare diseases (2009/C 151/02) https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2009:151:0007:0010:EN:PDF
13. https://www.efpia.eu/about-medicines/development-of-medicines/intellectual-property/help-us-make-rare-disease-even-rarer/
14. Boyle et al 2018, doi: 10.1136/archdischild-2016-311845
15. https://eu-rd-platform.jrc.ec.europa.eu/eurocat/eurocat-data - ref figure

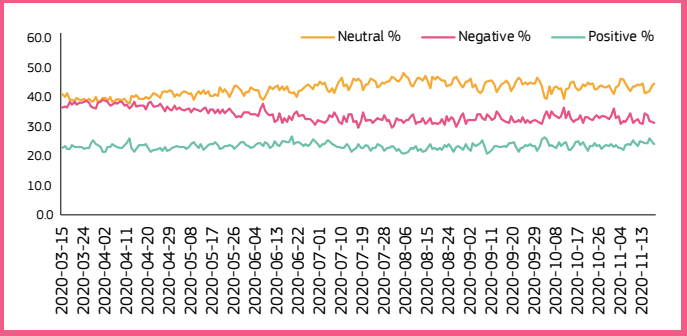
## ONLINE MEDIA REPORTING OF COVID-19: A NEW NORMAL?

In mid-March 2020 approximately two thirds of online news articles mentioned COVID-19, but following this peak, reporting volumes dropped over the summer, both in Europe and worldwide. However, since late August, reporting volumes from the EU Member States have been moderately increasing again. This increase is not observed elsewhere in the world, and may correspond to the high case numbers and reintroduction of restrictive measures across Europe.

The negative sentiment within the COVID-19-related articles from early in the crisis has reduced, with more neutral articles recorded since April. This leads to the questions: Are we entering a new normal and learning to live with the pandemic? Or is it a reflection of COVID-19 fatigue?

The same switch is observed for articles that mention the EU or the European Commission, although that change is observed slightly later. Volumes of reporting related to the EU response to the pandemic – RescEU, EU coordination of health response and the Health Union – were relatively low. The highest peak came with the State of the Union speech by President von der Leyen on 16 Septem-ber, where she stressed the importance "to build a stronger European Health Union" and with the adoption of the European Health Union package on 11 November, both with more positive than negative sentiment. Of the online media analysed, the sentiment related to this announcement was mainly positive (37%), or neutral (34%). Approval by the Commission of a contract with BioNTech-Pfizer for an initial purchase of millions of vaccine doses on behalf of all EU Member States, gained much higher reporting volumes, although here negative sentiment was slightly above positive.

**Figure: EM MS - Sentiment in all COVID-19 related news**



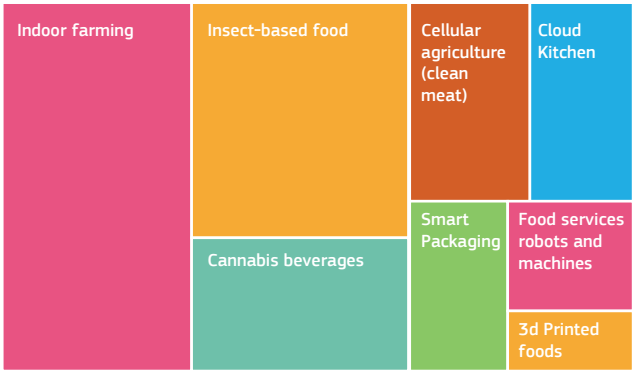

Source: EC JRC, Europe Media Monitor

## NUTRITION FOR HEALTH AND SUSTAINABILITY

Our diets will change in the future. Advances in nutrigenomics (which connects the human genome to nutrition and health), will lead to more personalised diets, based on individual taste, as well as health needs[1]. Sustainability of the planet is another driver leading to changing nutrition habits. Disruptive innovations include:

- Insect-based foods and cellular agriculture;[2]
- In vitro meat (cultured meat), made from animal muscle cells fed with proteins. This could be a viable alternative food source and reduce the environmental impact of meat production. A Dutch company could introduce in vitro burgers by 2022;[3]
- A Finnish food-tech start-up called Solar foods, creates 'food made from air', using bacteria that feed on hydrogen and CO2;[4]
- 'Synthetic milk' made from microbial cells is another example of an alternative food source.

**Figure: Emerging food trends (number of new companies)**




Source: PitchBook

Indoor farming, insect-based foods and cellular agriculture are growing sectors creating most new companies, a clear sign of a nascent trend.[5] Indeed, a total disruption of animal protein production could be driven by the use of microorganisms to produce food by 2035. Producers (companies) will need to follow legislation to meet European and national standards and to obtain pre-market authorisation from the European Food Safety Authority (EFSA).

Although we have good food tracing in Europe, improved traceability[6] of food sources and the application of new technologies (such as blockchain) will increase trust between companies and consumers and lead to more sustainable choices and higher acceptance by the consumers. Some European companies (including Nestle and Danone) are already piloting the first tests using blockchain.

## FUTURE OF MENTAL HEALTH

Good mental health is an integral part of overall health. Mental health challenges affect 84 million[7] people across Europe. They lead to premature mortality and a lower quality of life. The direct annual cost is over €600 billion i.e. 4% of EU GPD.

Mental health affects all ages, including the young, but elderly people are the most vulnerable. Traumatic events can have long lasting effects.[8] Exposure to risk factors in early life, such as family conflict, bullying at school, or having a lack of choices due to economic factors, can significantly affect mental well-being. Even before the coronavirus pandemic, mental disorders were among the top five causes of overall disease burden among children and adolescents.[9]

5.8% of COVID-19 patients have been diagnosed with mental illness despite having no previous history,[10] i.e. mental illness onset is a COVID-19 complication. The confinement has increased demand for mental health services and staff in uninfected people too.[11] Despite this, the pandemic has disrupted critical mental health services worldwide.[12,13] For example, in Madrid more than 60% of the beds reserved for psychiatric patients were diverted to COVID-19.[14] The WHO estimates the following disruptions:

- 75% of work and school mental health programs;
- 35% of emergency interventions; and
- 72% of services for children and adolescents.

The global antidepressants market is expected to grow following the surge in mental health issues due the pandemic, from €12.1 billion in 2019 to €24.3 billion in 2020.[15] The Commission has set up a dedicated space on 'COVID-19 mental health support'.[16]

1. Franhofer ISI, 50 trends influencing Europe's food sector by 2035
2. Cellular agriculture is the production of agricultural products from cell cultures. It uses a combination of biotechnology, tissue engineering, molecular biology, and synthetic biology to create and design new methods of producing proteins, fats, and tissues that would otherwise come from traditional agriculture.
3. https://www.fooddive.com/news/mosa-meat-gets-investments-and-support-to-bring-cultured-meat-to-europe-in/570236/
4. https://solarfoods.fi/
5. PitchBook, Emerging Spaces
6. RethinkX, Rethinking Food and Agriculture 2020-2030, https://just-food.nridigital.com/inside_food_dec19/changing_nutrition_trends_the_future_face_of_food
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11. https://apps.who.int/iris/rest/bitstreams/1310579/retrieve
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14. https://ec.europa.eu/health/eunewsletter/258/newsletter_en
15. https://www.globenewswire.com/news-release/2020/04/21/2019282/0/en/Global-Antidepressants-Market-2020-to-2030-COVID-19-Implications-and-Growth.html
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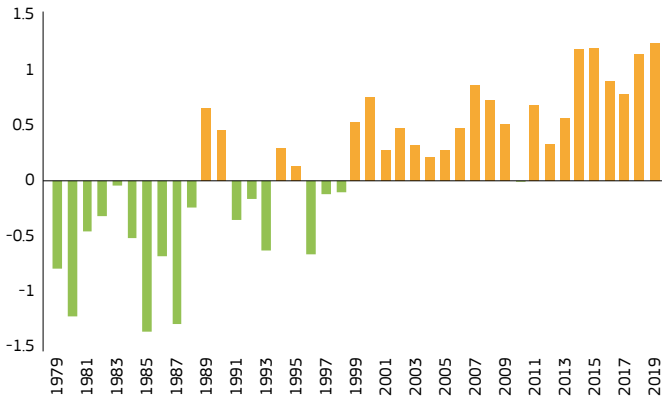
## HEAT WAVES GETTING MORE SEVERE

Heat waves are expected to increase in frequency, duration and magnitude as a consequence of climate change. Globally, in 2015 alone, 175 million additional people were exposed to heatwaves, compared to average year[1]. EuroHEAT estimated an increase in mortality ranging from 7.6% to 33.6% during heatwaves, for nine European cities.[2,3]

**Figure: Change in summer European temperature from average (°C).**




**Source: European Environment Agency[4]**

The effects are particularly severe in Southern Europe.[5] An increase in mortality of 2% in northern cities and 3% in southern cities is estimated for every 1 -degree increase in temperature above the city threshold level.[6] Heatwaves of long duration (i.e. those over four days) and high intensity, have a higher impact on mortality (1.5 to 5 times that of short ones). In the human body, all critical organs are affected by extreme heat, due to a dysfunction of the thermoregulatory system controlled by the brain.

Without immediate, drastic and long-lasting cuts in global greenhouse gas emissions, the 2°C global warming limit will be exceeded before 2050.[7] This will have a severe impact on Europeans' health, and will have global ramifications - from weather and food production to migration patterns.

## ANTIMICROBIAL RESISTANCE: A THREAT TO PUBLIC HEALTH

The WHO has declared that antimicrobial resistance (AMR), i.e. the ability of some bacteria to resist antimicrobial agents such as antibiotics, is one of the top 10 global public health threats facing humanity.[8] Resistant organisms are found in humans, animals, food, plants and in the environment (water, soil and air). They can spread from person to person, or between humans and animals, and can persist in food of animal origin.

Overuse of antibiotics and lack of compliance in their use by patients are some of the reasons for AMR. Additionally, the use of antimicrobials is omnipresent in agriculture. They are used to prevent disease in animals (including fish), in animal food and to stimulate animal growth. In some cases, antimicrobials are spread on plant crops. The estimated antimicrobial consumption in the livestock sector runs over 60,000 tonnes per year globally and is projected to grow steadily over the coming decades.[9]

There is a shortage of new antibiotics and other antimicrobial medicines to treat AMR and the few reagents under development are not sufficient to cope with the emergency.[10] AMR is estimated to be responsible for 25,000 deaths per year in the EU alone and 700,000 deaths per year globally. The inaction of regulators and society on this matter is projected to cause millions of deaths globally: it has been estimated that AMR might cause more deaths than cancer by 2050[11].

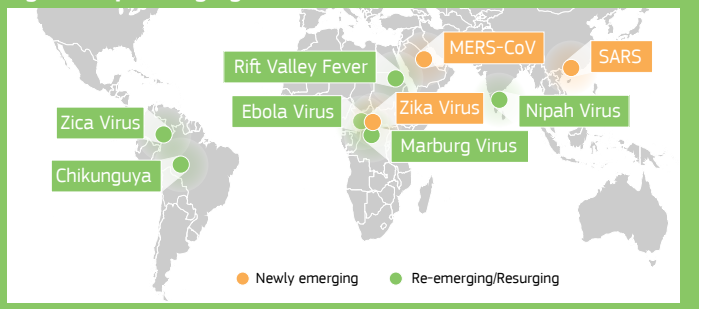
## RISK OF NEW PANDEMICS

The WHO tracked 1,483 epidemic events in 172 countries between 2011 and 2018.[12] Scientists warn that new diseases will emerge (or re-emerge) from the impact humans have on the environment and ecosystems. Firstly, by human encroachment of the habitat of wild animals. And secondly, due to climate change and the rise of temperatures in Europe - new disease vectors may appear, including mosquitoes and ticks.

- 70% of emerging diseases (Ebola, Zika, Nipah, West Nile), and almost all known pandemics (influenza, HIV/AIDS, COVID-19) are zoonotic diseases caused by microbes of animal origin; [13,14]
- Four mosquito types, (including the re-introduced Aedes aegypti), have been identified in Europe as potential threats for the transmission of Chikungunya, Zika, Dengue fever, West Nile virus and malaria. [15]
- In Western Europe, the number of people potentially ex- posed to Aedes-borne virus transmission was predicted to increase by 47.2-166.8 million by 2050' in two climate change scenarios. And by +90.3-220.9 million by 2080[16]
- The thawing of the permafrost could release pathogens, which were believed eradicated, such as small pox or bubonic plague, or those which have never before been in contact with humans.[17] The first example of this has been the non-infectious "Pithovirus sibericum", released from the Siberian permafrost.[18] Also in Siberia, following a heatwave in 2016 eight people and thousands of reindeers were infected with Anthrax following a heatwave

These cross-border threats require close surveillance and cooperation in medical research. Strategic foresight, combined with climate change modelling (using environmental, land use and population data) could help to predict which diseases will (re-) emerge. More research is needed to understand whether climate neutrality can stop or decelerate these outbreaks.

**Figure: Top emerging diseases**




**Source: US National Institute of Health**

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2. Athens, Barcelona, Budapest, London, Milan, Munich, Paris, Rome and Valencia
3. https://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/activities/public-health-responses-to-weather-extremes2/heathealth-action-plans/heat-threatens-health-key-figures-for-europe
4. https://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature-10/assessment
5. https://www.ecdc.europa.eu/en/publications-data/mosquito-borne-diseases-emerging-threat
6. https://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/activities/public-health-responses-to-weather-extremes2/heathealth-action-plans/heat-threatens-health-key-figures-for-europe
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9. ttp://www.fao.org/antimicrobial-resistance/background/what-is-it/en/ https://www.efsa.europa.eu/en/topics/topic/antimicrobial-resistance
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11. https://ec.europa.eu/health/sites/health/files/antimicrobial_resistance/docs/amr_2017_action-plan.pdf http://www.fao.org/antimicrobial-resistance/background/what-is-it/en/
12. https://apps.who.int/gpmb/assets/annual_report/GPMB_annualreport_2019.pdf
13. https://phys.org/news/2020-10-covid-onethere-animal-viruses-zoonotic.html
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16. https://journals.plos.org/plosntds/article?id=10.1371%2Fjournal.pntd.0007213
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## COMPASSIONATE RESEARCH

An organ-on-a-chip (OOAC) is a type of synthetic organ built on a microfluidic chip that can provide insights into organ functioning. Through a combination of cell biology, engineering and biomaterial technology, the chip simulates human tissue and can be used to predict a response to an array of stimuli and environmental effects.1 For example, they can accurately predict the safety and efficacy of drug candidates in humans, perhaps one day replacing the need for animal testing.

OOACs have been developed for about 10% of human body organs, including the blood-brain barrier, gut, kidney, lung, liver, female and male reproductive systems, the mammary gland, bone marrow, cardiac and skeletal muscle, and the bone-cartilage interface. But the complexity of the chips does not yet mirror that of real organs. To date, the OOACs available contain only one or two different types of different cells, unlike normal lung tissue which contains 40 different types of cells. Furthermore, OOACs are tested one at a time.[2]

The global OOAC market size is projected to reach €278 million by 2026, compared to €37 million in 2020, at a compound annual growth rate of 39.9% for 2021 to 2026.[3] This technological development could address the growing public concern about the use of animals in the pharmaceutical industry.

## ENHANCING HUMANS

Human enhancement is the natural, artificial or technological alteration of the human body to boost physical or mental capabilities. Most applications focus on replacing missing or reduced body functions:

| | | |
|---|---|---|
| Replacing capabilities | **3D-printed organs** [4] | Grow and replace skin using the protein collagen |
| | **Bionic eye** [5] | Blindness |
| Boosting capabilities | **Exoskeleton** [6,7] | External wearables providing workers with artificial strength |
| | **Neurolink**[8] | Brain-computer interfaces allowing computer interaction at neural level |
| | **Nootropics**[9] | Substances boosting brain performance |
| Additional capabilities | **Dermal Tattoo Biosensors** | Skin biosensors to manage metabolic processes, diabetes, and liver failure |

While several enhancements are already on the market, such as the exoskeleton, others are still in the initial phases of development. Human enhancements promise to improve human condition, but they also come with grave risks and profound ethical questions. Will such technologies be used responsibly? Will there be a divide between those who can afford these technologies and those who cannot? Will new categories emerge in society, i.e. the enhanced and the rest, and what consequences will this have for society and democracy? These future realities might need to be considered sooner than you think.

## NANOMEDICINES: A GIANT STEP?

Nanomedicines are pharmaceutical products that use nanoscale materials to target disease far more efficiently than conventional medicines. The use of the nano-sized carriers can deliver a drug to a specific site of a disease. Certain nanomedicines only release the drug upon stimulation (temperature, pH, hormones) and underspecific conditions in the body. Nanomedicines are instrumental to implementing personalised medicine, as they can specifically target diseased tissue of patients.[10]

The main areas of application of nanomedicines include cancer treatment, infectious diseases, and inflammatory and degenerative disorders. The so-called theranostic[11] agents combine diagnostic and therapeutic action, allowing imaging of cancer cells prior to delivery of the therapeutic molecule.

More than 50 nanomedicines have already been approved in the EU and more than 100 are in clinical trials.[12] For example:

1. Opaxio, a drug activated by enzymes, targeted towards ovari- an and lung cancer, is in Phase III clinical trials;[13]
2. Hybrid nanostructures for cancer treatment that are based on the combination of two radioactive drugs, one for diagnosis and the second for treatment.[14]

## THE UNSUSPECTED ME – MY MICROBIOME

Our body is a host to other living beings. The gut microbiome contains trillions of micro-organisms (bacteria, fungi and viruses) – as many as there are cells in the human body. Indeed, a person contains 150 times more microbial genes than human genes.[15]

Microbes in our bodies play important life functions: from training our immune systems, to managing anxiety and pain (via the gut-brain axis). 95% of the body's supply of serotonin, which is responsible for happiness or depression, is produced by gut bacteria.[16] Diet, lifestyle and external factors, such as the use of antibiotics, influence the composition of the microbiome, and it is in continuous change throughout the course of our lives.

Antimicrobial resistance (AMR) can deteriorate our microbiome. There is growing evidence from research that early-life antibiotic use is associated with the rise of chronic diseases.[17] Individuals with Parkinson[18] or Alzheimer[19] exhibit distinct microbiome changes. Diseases such as cancer, autoimmune disorders, multiple sclerosis, and autism spectrum disorder are also influenced by processes within the gut microbiome.[20]

Better understanding of the role of the microbiome in health and diet can open the doors to personalised treatments.[21,22] The human microbiome market is expected to reach €565 million by 2023, up from €252 million in 2019.[23] In February 2020, the French company MaaT Pharma raised €18 million for its microbiome-based cancer treatment.

1. https://biomedical-engineering-online.biomedcentral.com/articles/10.1186/s12938-020-0752-0
2. https://www.bio-itworld.com/2019/11/20/will-organ-on-a-chip-models-be-viable-alternatives-to-animal-testing.aspx
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17. https://www.neurodegenerationresearch.eu/cs/2017/03/parkinsons-disease-linked-to-gut-microbiome/
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