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Global Trends in Artificial Intelligence and Their Implications for the Energy Industry

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Executive Summary

Artificial intelligence (AI) has become an intrinsic part of our ever more digitalised world. Be it in research, the economy or in society, the topic of AI is gradually suffusing almost all aspects of our lives. The same is true for the energy industry, which is undergoing immense change like almost no other sector and is searching for new, integrated solutions. The massive restructuring of national and international energy systems is also characterised by comprehensive process optimisation in order to free up resources for greater financial leeway and to completely reinvent businesses with the help of AI. AI is a beacon of hope, if not a fundamental building block, for achieving the goals of a CO_2-free energy system against the background of economic, ecological and social requirements that are just as – if not more – stringent than before.

This report aims to identify and shed light on current AI trends and to derive the first implications of these trends for the energy industry. Firstly, over 100 cross-sector national and international studies and reports were analysed in order to provide answers to the following questions: How quickly will developments in AI advance and what role does the quality of datasets play? Is AI realistically capable of matching or even surpassing all aspects of human intelligence? In which sectors will these developments penetrate the increasingly global markets the fastest? How are different countries and regions positioning themselves around this topic and how are they investing in it? What role do research and politics play? How can we learn from international best practices and use them to derive recommended courses of action for the integrated energy transition?

The dominance of datasets

The highly dynamic evolution of AI is driven by the global digitalisation trend, which is based on the exchange of an enormous amount of information. The vast number of datasets generated by different digital technologies and sensor systems – sometimes within milliseconds – is growing exponentially and it is estimated that the global exchange of data will be 175 zetabytes (a figure with 21 zeros) by the year 2025. It is also assumed that the proportion of real-time data will increase to 30% by this time. As a result, a user would interact with a dataset every 18 seconds on average (Kroker, 2018).

The effects that AI-based systems have and will have on society are thus incalculable at present. Consequently, not everyone views the technology as unambiguously positive – in many sectors there is a great deal of uncertainty. This has also been shown by the white paper on artificial intelligence by the European Commission. It discusses not only the improvements brought by rapidly evolving AI for all industry sectors (e.g. optimised healthcare, efficiency gains in agriculture and mitigation of climate change), but also the potential risks associated with it (EU Commission, 2020). Following on from the fact that any AI technology can only be as strong as the dataset it was trained with is the issue of data security and sufficient data protection. In future, it will become increasingly important to show which digital information comes from which addressee. The project GAIA-X by the German government for the development of an open, interconnected data infrastructure for Europe aims, for example, to increase data sovereignty in the exchange and use of data and to make this data available for AI applications (Federal Ministry of Economics and Technology, 2019).

In the energy industry, too, the required granularity of datasets and measurement intervals has been the subject of lively debate for many years. Some actors insist on a 15-minute interval and point to the many processes in the energy industry that are based on this, whereas other actors are calling for significantly smaller measurement intervals so that the potential of digitalisation can be fully exploited.

In the context of AI, too, it is clear that the level of data granularity will depend on the individual application. It is not possible merely to generalise that information flows every few seconds will be necessary or even useful for every form of AI. Rather, in view of the amount of data to be analysed and the inevitable associated energy requirements, the benefits of using AI in a specific application and the effort involved must also be assessed.

Changing companies, business models and professions

Because of AI, companies are faced with fundamental changes as well as the need to transition to digitally and artificially-assisted process control as quickly as possible in order to remain competitive. At the same time, IT-supported and self-optimising processes are fuelling a whole host of new business ideas that have an impact on all areas of life. Be it automatic surveillance of beaches using drones that can detect dangerous situations by themselves, an app that describes the surroundings to the visually impaired using a camera and a loudspeaker, or an AI algorithm that generates optimised transport route capacity utilisation plans for more intelligent traffic management – the possibilities are endless.

Around the globe, AI will undoubtedly transform the world of work, creating new jobs while also reducing demand for certain existing roles. It is difficult to predict which sectors will be affected to what extent, since almost all roles will contain a digital component in the future. Only professions with a highly social and/or cognitive requirement profile appear to be safe in the medium term, since, as it stands, AI is not considered capable of mimicking these extremely complex human traits any time soon.

This change will not stop short of the energy industry, either. It is inevitable that processes which will, in future, be able to be implemented more efficiently and effectively by means of digital technologies will also make their way into the energy sector. This aspect should be viewed as fundamentally positive, as once centralised energy systems have been broken down into several smaller, decentralised subsystems across the globe, it will only be possible to keep a handle on the entire system using digital technology and artificial intelligence. Machines will gradually alter certain jobs and eventually replace them. Employers with an eye to the future are already preparing for this change by creating job prospects for the affected job groups.

The global race for supremacy

On an international level, the race for AI supremacy has kicked off, with nations traditionally leading the pack in all things AI such as China and the USA facing increasingly stiff competition from other countries. It therefore comes as no surprise that there has been a significant increase in investments in this sector. In total, more than 30 billion USD has been invested in AI start-ups since 2011.

In the USA, the Big Four alone – Google, Apple, Facebook and Amazon (GAFA) – pumped 23 billion USD into the artificial intelligence sector between 2010 and 2018. In 2018, AI companies in the USA were able to achieve a turnover of 9.3 billion USD – an increase of 72% compared with the previous year (CBInsights, 2018). Of the 15.2 billion USD invested in AI start-ups around the world over the last eight years, half flowed into Chinese AI start-ups – in 2016 it was just 11% (Bughin et al, 2018). In Israel, the funding for AI start-ups increased by 70% year-on-year to 1.9 billion USD in 2017 (Singer, 2018). In contrast, expenditure in much more populous Europe was far lower, totalling just 3.6 billion EUR for AI start-ups (Daws, 2019).

A survey of 250 executives in the German energy industry also indicates that the European approach to investment in AI is more defensive. According to this survey, only seven per cent of the companies consulted had invested in AI by summer 2019 and just six per cent plan to use AI and have budgeted for it.

Sixteen per cent plan to invest in AI within the next five years and 32 per cent envisage making an investment at some point in the future, but have yet to make any concrete plans. Thirty-four per cent of the companies surveyed, and therefore the largest group, see no need to invest in AI.[1]

Different approaches to research

In the field of research and development (R&D), too, global trends indicate a significant increase in activities relating to the various disciplines of AI. This is particularly clear from the rising number of AI publications, especially in the field of machine learning. At the same time, more and more patents relating to AI are being filed every year – above all in China, followed by the USA and Japan.

Looking at research activities in the various regions of the world, it is clear that in Europe there is a strong focus on basic research, with a large number of initiatives for AI research institutes. In the USA, research into AI is taking place above all in the private sector, and the Defense Advanced Research Projects Agency (DARPA) is also involved in AI research. In China, companies, academic institutions and the government are all working closely together in the field of research, whereas in Israel attempts are being made to train more and more AI experts at universities in order to secure the future of AI research there.

The technological infrastructure also has a big influence on research and development in the field of artificial intelligence. The stronger the IT infrastructure, the better the conditions for developing high-performance AI. The USA dominates when it comes to the manufacture of computer chips and has an extremely high computing capacity with 116 supercomputers.[2] Only China boasts more, with 220 supercomputers, in stark contrast to Europe with 96 and Israel with none at all. Thanks to its high number of Internet users and the relatively "uncomplicated" data collection process, China also has access to an enormous pool of data for training the AI algorithms. In Europe, the use of data is more heavily restricted due to stricter regulations.

In the energy industry, dynamic and innovative applications are the speciality of start-ups, which are developing digital solutions for the energy transition. However, they often lack the equipment and necessary resources to bring their innovations onto the wider market. Collaboration with large corporations and research institutes may be the ticket to developing a common AI vision in the energy sector, which could in turn make it possible to devise a variety of solutions for digitally transforming the energy system more effectively. Targeted training programmes that combine expertise from the fields of IT and energy also form an important basis for the future.

It has been shown that the various political and economic systems have the greatest influence on the speed of development in the field of AI. In China, it is apparent that data is collected and analysed above all for implementing the government's agenda. An example of this is the Chinese social credit system, in which citizens are awarded points based on the data gathered about them, and depending on the number of points amassed they either receive special privileges or face severe penalties. In Europe, this approach is viewed very critically, as it is associated with a flagrant disregard for privacy and personal rights. Protecting people's privacy and user data plays a particularly important role in Europe, which is very different to the approach in the USA and especially in China. However, this attitude inevitably restricts the scope for experimentation with data.

[1] dena Analysis "Artificial Intelligence for the Integrated Energy Transition" (2019): The full report can be viewed here: https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2019/dena-REPORT_Artificial_Intelligence_for_the_Integrated_Energy_Transition.pdf.
[2] Supercomputers are the most powerful computers of their time and are ranked in a top 500 list every six months.

Over recent years, both the European Commission (EC) and individual European states have presented an AI strategy. A key component of these strategies is the ethical handling of digital information and the changing conditions in the professional world. The most recent developments under the new President of the European Commission, Ursula von der Leyen, point to the EU's goal of taking on the role of "key global digital player" in the future, with a particular emphasis on multiplying AI companies and AI experts (Hoppe, 2020). In terms of data availability, Europe is trying to make up for lost ground with the recently introduced Breton data strategy, whose aim is to make it easier for developers to access personal protected and valuable data and to create data rooms in order to improve knowledge transfer between the various actors. The exponential growth of data availability across the various industries and the efforts to create a European data cloud are promising signs of greater AI dynamism in Europe (ibid.). In the case of data rooms, the focus is still on the traffic, financial and health sectors, but it should also be extended to the energy sector, which is no less important. An example of this is the environmental data cloud in the AI strategy of the German government. In contrast, the American government is putting a great deal of trust in universities and the US military when it comes to AI research. Indeed, under the Trump administration, a clear, discernible strategy for AI is yet to emerge. In Israel, the Israel Innovation Authority (IIA) is calling on the government to devise an AI strategy. It is hoped that new regulations, such as corporate tax cuts for high-tech companies, will provide further incentives for the development of AI.

The potential of and challenges associated with AI in an energy context are gaining international attention

Thanks to the increased global understanding of the climate problem, there is growing interest in using digital technologies in an energy system that will in future be far more complex and that is becoming increasingly decentralised. Accordingly, some nations have recognised the potential offered by automatic information exchange and automatic information processing for the energy transition and have already incorporated this into their AI and digital strategies.

Nevertheless, the high energy consumption of AI technologies to date should not be ignored. As such, it will become increasingly important to develop more energy-efficient AI. Both politics and industry must pitch in in order to establish AI in the energy industry via the implementation of pilot projects and use cases.

Time to act – how can we apply AI to the energy transition?

The present analysis of a selection of recommended courses of action serves to demonstrate how AI can be applied to the integrated energy transition. This includes, first and foremost, researching and developing **energy-efficient IT technology in Europe** as well as a comprehensive **analysis of the energy demand** over the course of the rapidly developing use of various AI methods weighed up against the benefits of these methods. It must be clarified where the computing centre is located, for which computing processes AI is being used and consuming energy and whether AI can be operated using CO_2-free energy sources. An investigation devoted to these highly complex issues is essential in order to steer developments in the right direction at an early stage. **Europe and the energy sector can lead the way and serve as a role model for the world by clearing and signposting development paths that are ecologically and economically balanced.**

Just as vital as the issue of energy consumption is the issue of how to deal with data used for training various forms of AI. The security of datasets and the adequate protection of digital information of any kind must be ensured, especially if the AI process or the way in which results achieved using AI is not completely transparent.

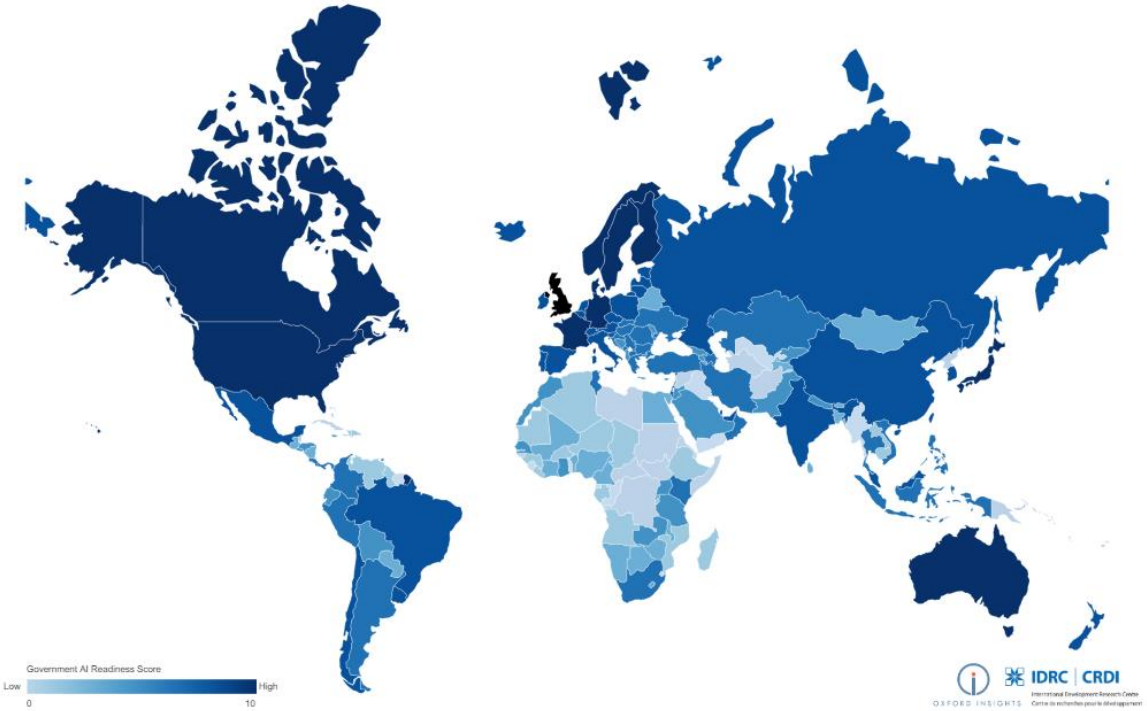
If we can expect the use of AI to be of great global significance in the future from an economic perspective as well and if we see a strong correlation between the success of AI and the use and quality of data, then we must ensure that it is possible to accurately trace, classify and evaluate the source of the data. Accordingly, it is also of vital importance for the energy industry to **set up the first expert panels and develop models** that deal with the issue of how **data origin and data use can be traced using technology and economically exploited**.

A **cross-technology pilot laboratory**, inter alia for testing the potential of AI for the energy transition and for developing synergies with blockchain technology, **integration into existing programmes for supporting and advising AI start-ups in the energy industry** as well as an **open and interdisciplinary discussion forum** on various topics relating to the development of artificial intelligence for the energy industry, should be the main pillar of the Future Energy Labs set up by dena.

1 Global AI developments

The terms “artificial intelligence” and “energy transition” are used in the media almost every day. It became clear that humanity has a duty to combat climate change long before the Paris Agreement was adopted. And it is also clear that digitalisation and the technologies associated with it will play an important role in ensuring the success of the energy transition. Without a digitally-assisted process landscape, it will not be possible to efficiently monitor an energy system that will in future be highly decentralised. AI offers potential for a wide variety of applications, as demonstrated by dena in the analysis “Artificial Intelligence for the Integrated Energy Transition”, published in September 2019.[3] However, a representative survey[4] of 250 managers from the German energy industry conducted on behalf of dena showed that German companies are still rather reluctant to invest in AI. Only 7% have already invested in this field.

In order to better gauge the suitability of artificial intelligence for use in the energy industry, it is helpful to analyse global developments in this field. The aim is to ascertain whether the AI activities in other regions and sectors can be transposed to the energy industry. To do this, the results from a large number of studies and reports were considered and implications for the topic area of energy were derived. As such, the present analysis will not only take a look at the energy sector, it will firstly provide a summary of current AI trends in four selected countries and/or regions identified as pioneers in AI. These are the USA, China, Israel and Europe. The general aim is to identify global trends and find a way to apply them to the domestic context. Secondly, the transposability of these trends to the energy industry will be examined and concrete recommended courses of action for using AI for the integrated energy transition will be proposed.



[3] For more information, see the dena analysis “Artificial Intelligence for the Integrated Energy Transition”, see above.

[4] From 24 April to 8 May 2019, Midline Energy surveyed 250 managers of companies from the energy industry in Germany on behalf of dena on the topic of “Artificial Intelligence in the Energy Industry”. The majority of companies surveyed are involved in traditional areas of the energy industry, such as the consumption, trade, generation and transportation of energy. Two thirds of the companies employ between 10 and 49 staff, 11% have 50 to 99 employees and 22% have at least 100 employees.

The Government AI Readiness Index elaborated in 2019 by Oxford Insights and Canada's International Development Research Centre (IDRC) shows how well prepared governments of UN member states are for the use of AI. 11 input metrics were grouped under the four clusters of governance, infrastructure and data, skills and education, and government and public services and then analysed. The top 10 countries are those with a strong economy and innovative private sector. The top 20 places in the ranking are dominated by Western European countries but include no African or Latin American countries. Surprisingly, China occupies a relatively low position on the list at number 20, but this is above all due to a lack of data (Miller et al, 2019).

Rank (out of 194)	Country	Points (from 0 to 10)
1	Singapore	9.186
2	United Kingdom	9.069
3	Germany	8.810
4	USA	8.804
5	Finland	8.772
6	Sweden	8.674
7	Canada	8.674
8	France	8.608
9	Denmark	8.601
10	Japan	8.582

Table 1: Top 10 ranking of the preparedness of governments for AI 2018/19 (Miller et al, 2019).

1.1 The rise of artificial intelligence in research

"Artificial intelligence will reach human levels by around 2029. Follow that out further to, say, 2045, and we will have multiplied the intelligence – the human biological machine intelligence for our civilisation - a billion-fold." – **Raymond Kurzweil**, Director of Engineering at Google

The number of AI publications is constantly rising

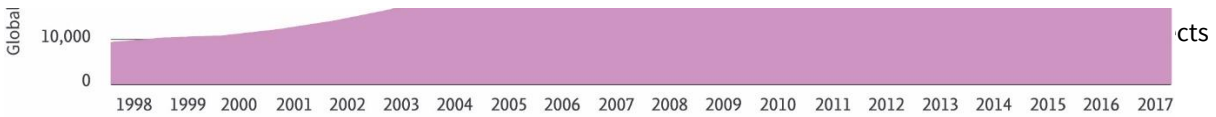


Figure 1 shows the growth of AI publications since 1997. The graph also includes conference and tender papers. In 2017 alone, approx. 60,000 publications relating to the field of AI were published, corresponding to an average annual growth rate over the last 5 years of 12.9% (de Kleijn et al, 2018).

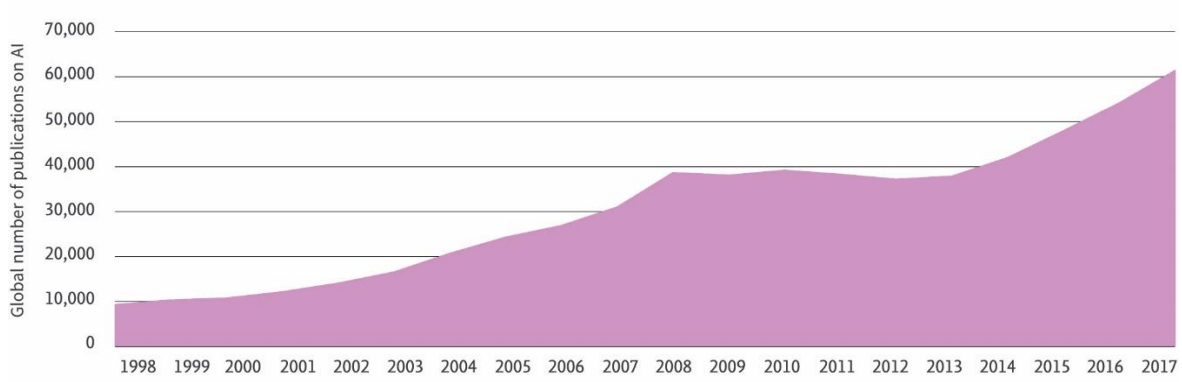


Figure 1: Annual number of AI publications (all types of document) from 1997 to 2017 (de Kleijn et al, 2018).

The number of publications in the fields of machine learning and probabilistic reasoning, neural networks, and computer vision saw the most rapid growth over recent years (ibid.).

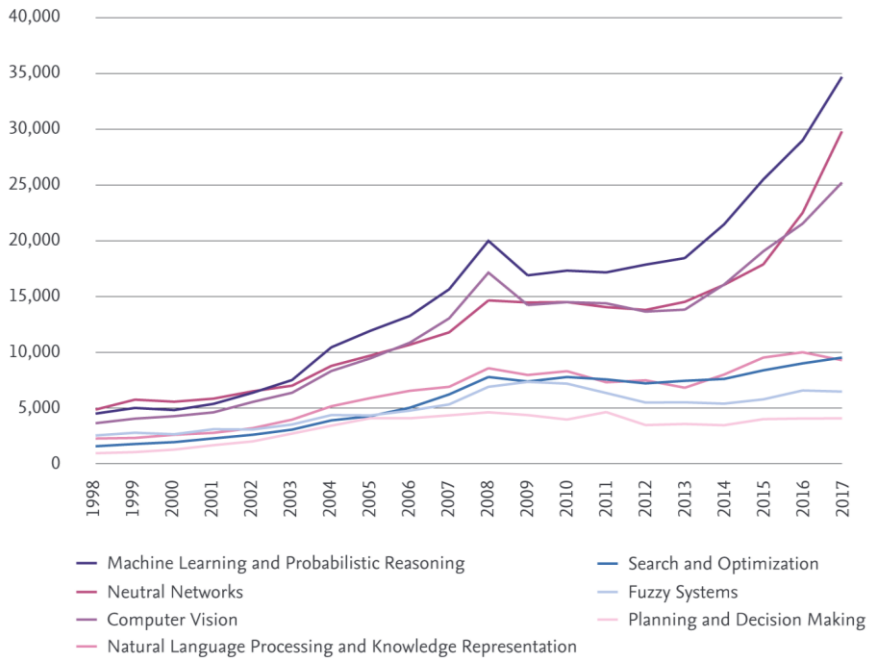


Figure 2: Annual number of AI publications by keywords occurring together or in isolation (de Kleijn et al, 2018).

Enormous growth rates for patents on deep learning

The number of worldwide patent applications in the field of AI has also continued to increase over recent years. Looking at the number of AI patents, China is in the lead, followed closely by the USA and Japan. Taken together, these three countries account for 74% of all AI patents globally (Tsinghua University, 2018). According to the World Intellectual Property Organisation (WIPO), 50% of all AI patents – a total of 170,000 – have been filed since 2013. Of these, the majority relate to the topic of machine learning. The fastest growing AI field is deep learning, which is used in speech recognition, among other areas. With a growth rate of 175% between 2013 and 2016, deep learning is far ahead of all other AI fields, the average growth rate of which is a comparatively paltry 33% (UN News, 2019).

General research activities

As the Relative Activity Index (RAI) shows, the focus of the various areas of research and development defined by the OECD varies greatly in the regions studied. The numbers indicate the proportion of research activities relative to the total global research activities in the relevant category. As shown in the graph, there is a strong focus on the humanities in Europe and the USA, with the USA also focusing on healthcare. However, in China, most of the AI development is strongly concentrated in agricultural science and engineering, with strikingly little activity in the humanities (de Kleijn et al, 2018).

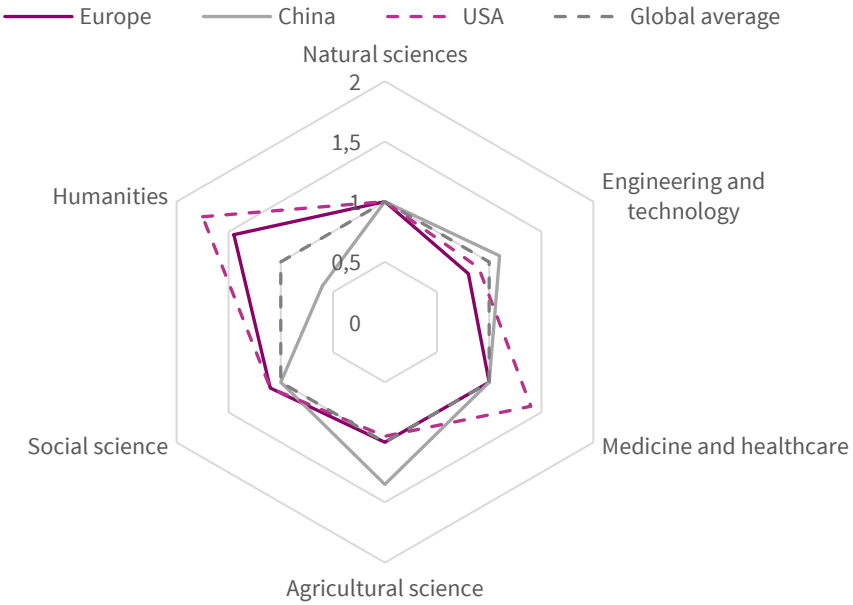


Figure 3: Relative Activity Index of publications by category and region, 2017 (own graphic based on de Kleijn et al, 2018).

When will strong AI arrive?

In comparison to weak AI, which is currently in use and can only solve specific problems as it is only intelligent in certain areas, strong AI or Artificial General Intelligence (AGI) encompasses all aspects of human intelligence (dena, 2019). As to the question of when AGI will be technologically available, there are two schools of thought that are diametrically opposed to one another: one is that strong AI will become reality within the next few years and the other is that it is basically impossible to achieve.

AI experts have been asked in a great number of surveys about their opinion on how many years it will take for AI to reach the level of human intelligence. None of these surveys produced a clear result. In 2016, for example, 352 machine learning researchers were asked to give their assessment on the progress of AI and the temporal availability of specific AI functions. “High-level machine intelligence” (HLMI) was in this case defined as a machine which can perform all tasks better and more cheaply than a human without external help. The study revealed a 50 per cent chance that HMLI can be achieved within the next 45 years and a 10 per cent chance that it will be achieved within 9 years. Another interesting point was the very different perception of Asian experts (30 years) and American experts (74 years) (Grace et al, 2017).

Dr Aljoscha Burchardt

Deputy Spokesperson for the German Artificial Intelligence Research Centre (Deutsches Forschungszentrum für künstliche Intelligenz, DFKI) in Berlin

What global developments can be seen in AI research?

The machine learning trend, in particular when it comes to neural networks, shows no sign of slowing. The issues of transparency and explainability are also gradually being incorporated into research work. But these issues then take you back to square one, throwing up questions such as how to bring general world knowledge to the machines and how man-machine dialogue can be conducted on an equal footing.

How do researchers view current developments towards a weak and a strong AI? When do you think strong AI will arrive?

With the resources we currently have, I do not think we are anywhere near close. We will either understand at some point how our brain works and transpose its functioning to machines (rather unlikely) or artificial insight, artificial consciousness, etc., will come about by chance, for example on a supercomputer. Theoretically, we could also find another method that does not rely on our brain as a model, like when we humans first wanted to build aircraft using leather wings, but then invented propellers and turbines. But I also consider this to be rather unlikely.

In what areas is AI already being used intensively, and what areas harbour the greatest potential?

AI is used, for example, in web searches and medical research. The potential it offers is more or less as high as that of electrification, the Internet and digitalisation. AI generally helps where tasks are repetitive, i.e. when you can accurately predict future reactions based on past reactions. One example of this from my field is the translation of texts. Here, you can learn quite well from existing translations.

What role does AI play in the energy industry?

The possibilities range from assisting with multilingual communication, e.g. when planning transnational routes, to controlling smart grids. There is nothing that AI cannot help with.

As an AI nation, Europe is widely considered to lag far behind (partly because of its focus on basic research) the USA and China, which are quicker when it comes to development and implementation. Where do you see opportunities for European actors to catch up in the AI race?

When it comes to big data end-customer business, our prospects do not look so bright at present. One approach will definitely be to develop industrial solutions for small and medium-sized enterprises (SMEs), which for example require less data and generally have great need for customisation. Classic AI topics such as knowledge modelling and planning which many international actors who rely on machine learning alone have no understanding of could also play a role.

1.2 How does artificial intelligence influence the economy?

"The pace of progress in artificial intelligence is incredibly fast. Unless you have direct exposure to groups like DeepMind, you have no idea how fast – it is growing at a pace close to exponential. The risk of something seriously dangerous happening is in the 5 year time frame, 10 years at most." – **Elon Musk**, Entrepreneur and Investor (incl. Tesla and SpaceX)

AI is changing the world of work

Artificial intelligence and automated processes can be expected to have a big influence on all business entities and sectors across the world. The job market and its requirements for prospective employees will change – new areas of activity will emerge, long-standing industries will be lost and consumer behaviour will change. In addition, new business models will be developed and higher production rates will be achieved by companies thanks to high automation rates. Finally, technological progress will create both divergences and convergences between nations. Expressed in figures, AI will contribute an additional 13 to 15.7 quadrillion USD to the global economy by 2030 at an annual growth rate of 1.2% – simply by integrating it into existing business processes (Bughin et al, 2018; Berriman et al, 2018).

This growth will be driven, on the one hand, by an increase in productivity, which will account for 55% of AI-induced GDP growth from 2017 to 2030, and, on the other hand, by an increase in demand. Taken together, these two effects will lead to higher incomes, improved welfare through higher tax revenues and increased demand for labour (Barnard Roberts et al, 2018).

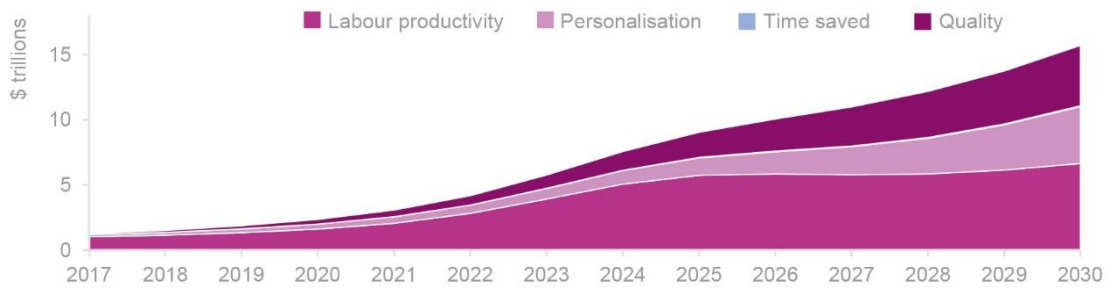


Figure 4: Global impact of AI on GDP (Barnard Roberts et al, 2018).

Initially, progress will be relatively slow as the world gets to grips with the new technology, but then it will be pushed into a higher gear by competition. According to estimates by McKinsey, by 2030, approximately 72% of all companies will have introduced AI and the economic gain will be three times higher than in the first five years of its development. This will likely manifest itself predominantly in developed nations, whereas the benefits will be smaller in developing countries. Advanced economies are relying on new growth drivers to boost their sluggish growth rates and will therefore likely invest more in disruptive technologies than emerging economies (Bughin et al, 2018).

There will also be profound changes when it comes to the nature of work. The fields of activity will thus shift away from repetitive tasks and towards tasks with social and cognitive requirement profiles (ibid.). In total, 326 million jobs could come into contact with artificial intelligence, with the risk of employees being affected by automation processes depending on the industry they are in. The jobs most threatened by automation are those in transportation and warehousing (with 52% being endangered) and in manufacturing (45%). The effects on the latter will be particularly pronounced due to the higher volume of employees in this sector. In contrast, jobs in the fields of healthcare and education will be less affected due to their strong social focus.

On a macroeconomic level, both effects – loss and creation of jobs – will cancel each other out by 2030 (Barnard Roberts et al, 2018).

Increasing investment in AI

The heightened global interest in AI technologies is reflected in the ever-growing number of investment funds, venture capital firms and corporate investors putting their capital resources into AI start-ups. This is especially true for the autonomous driving sector, which accounted for 30% of all private investments into AI in 2018. The constant rise in total investments demonstrates that investors are increasingly banking on the potential of artificial intelligence. In total, more than 50 billion USD have been invested in AI start-ups since 2011, with the USA and the People's Republic of China leading the way. Two-thirds of the total global investment volume flows into American companies, which is hardly surprising given the high level of funding from within the USA itself – accounting for 70 to 80% of all venture capital investments in the entire world across all technologies. Chinese companies have registered the fastest growth, with 36% of total global investment in 2017 compared with just 3% in 2015 (OECD, 2018).

Viewed globally, the AI trend is also mirrored in the number of investment deals – which have increased from less than 200 transactions in 2011 to 1,400 deals per year across the world within the following six years – which equates to a cumulative annual growth rate of 35%. Furthermore, the average amount of money invested each time has increased globally. This is testament to a higher degree of maturity, both in AI technologies and in the strategies of the investors, since higher investment sums are concentrated on fewer AI firms. For example, in 2012, there was only one deal of between 10 and 100 million USD, but in 2018 40% of all investments had a value in this range. 4.4% of all deals even had a value of more than 100 million USD – in 2012 there was not a single one (ibid.).

Dr Rainer Hoffmann

Senior Manager Data & Analytics EnBW Energie Baden-Württemberg AG

What effect does the increased use of AI algorithms have on the economy?

Artificial intelligence has a very positive impact on the economy. Firstly, processes can be automated thanks to AI and, secondly, entirely new products and business models are created. Routine activities that actually require human perception, e.g. visual inspection of products, can now be performed very well by AI.

As a result, many jobs could potentially become more attractive, as monotonous work steps that have to be repeated again and again can be got rid of. The focus can instead be placed on tasks which require individual human action. However, AI can also achieve things that a human would never be capable of, such as the continuous evaluation of millions of data points in order to monitor the condition of plants. This opens the door to products and services that could not exist without AI.

Do you think that the business community is investing enough in AI?

As far as I can tell, it is above all firms that have understood the added value of AI that are investing in this technology. However, I have got the impression that many companies in Germany do not know how to approach AI in concrete terms. I therefore suspect that companies' uncertainty is behind hesitant investments. But I am convinced that there is potential to use AI in every company. There are a wide variety of options, for example in the field of "Computer Vision" or "Natural Language Processing".

Therefore, I hope that more and more companies discover the potential of AI for themselves. It has a lot to do with culture and understanding and not really anything to do with complicated algorithms.

Looking at the booming market for AI experts in Asia and the USA – how can a European company attract and retain AI specialists?

At the moment, it is not at all easy to recruit specialists. Firstly, not everyone who claims to be an AI expert in their CV is one. Getting in good employees with relevant experience is very difficult – not least if your location is not especially attractive. The presentation of exciting use cases at conferences and meetups is certainly helpful for recruitment. But I am a strong advocate for internal qualification of employees. Before looking for experts from outside, you should first see who inside is enthusiastic about the topic. Nowadays, the options for further training are very diverse and affordable.

Do you think that companies will benefit financially from AI? If yes, how exactly?

Many companies are already gaining experience in dealing with AI. In this regard, it will become critical over the coming years to use AI efficiently. Those who can do this and can apply AI commercially will surely benefit financially.

Do you think that the use of AI creates more opportunities or more risks for business?

For me, the opportunities are clear-cut. If I use AI responsibly and understand its effects, i.e. if I also manage the risks, I will benefit from AI. Risks arise if I use AI without having a clear understanding of it. Thanks to self-service analytics tools, more and more people can develop AI applications without having to write a line of code themselves. However, if untrained people try to do it, what they produce may have undesired consequences. We should always think of AI for what it is: a collection of statistical procedures, the outcome of which only ever applies with a certain probability. And ultimately, we humans must learn to live with and be able to interpret this uncertainty.

1.3 How is artificial intelligence viewed in society?

"Perhaps we should all stop for a moment and focus not only on making our AI better and more successful but also on the benefit of humanity." – **Stephen Hawking**, Theoretical Physicist and Astrophysicist

Artificial intelligence is not only significant for industry, consumers across the world are also affected by it. For this reason, a large number of surveys have been conducted in order to better understand public perception of AI. Both demographic and geographical differences were factored into considerations.

In the report "AI-Ready or Not: Artificial Intelligence Here We Come!", the communications consultancy firm Weber Shandwick analysed the attitude of consumers towards AI in the USA, China, Canada, the United Kingdom and Brazil and derived implications for the marketing world. According to this report, consumers in China seem to know a fair amount about AI, whereas in the USA and United Kingdom knowledge levels are lower. At the same time, AI is perceived as harbouring relatively little potential in both Canada and the United Kingdom. China and Brazil are the most optimistic, both in terms of the influence of AI on society and in terms of the influence on the individual (Weber Shandwick, KRC Research, 2016).

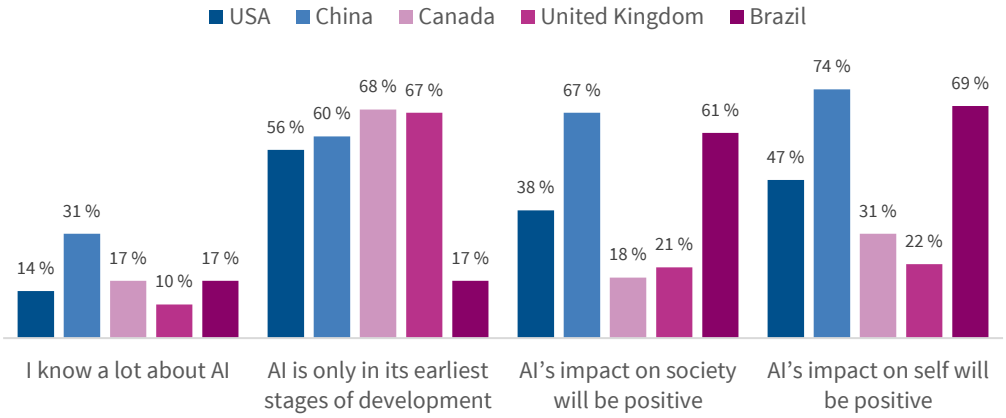


Figure 5: Country-specific perceptions of the effects of AI (own graphic based on Weber Shandwick, KRC Research, 2016).

There also appear to be geographical differences with regard to the expected benefits of AI: In China, 89% of those surveyed believe that the greatest benefit of AI is time savings, whereas in the USA (71%) and the United Kingdom (56%) most think it is the completion of tasks that are too difficult or dangerous for people, and in both Canada (73%) and Brazil (82%) most hope that AI will make it easier to access relevant information and news. At the same time, there is a great deal of uncertainty among consumers. In all five countries, the greatest worry is that AI could be used for criminal purposes (USA: 92%, China: 86%, Canada: 98%, United Kingdom: 89%, Brazil: 96%), followed closely by the possible loss of jobs and the fear of less security around personal data and privacy (ibid.).

In the Dynamic Digital Consumers Survey, Accenture consulted 26,000 consumers in 26 countries and derived four important findings from the results: AI is taking on a central role in the life of consumers, new interactive functionalities are increasing the demand for smartphones, new application models are being created and consumers would like more control over the use of their data. By way of example, consumers see the greatest benefit in the use of computer-based applications instead of human advisers in the following areas. Above all, the constant availability of advisory services seems to be a decisive advantage for consumers (Björnsjö et al, 2017).

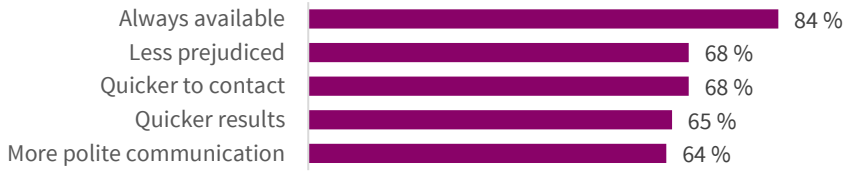


Figure 6: Percentage of survey participants who agree with the stated advantages of computer-based applications (own graphic based on Björnsjö et al, 2017).

An analysis of all articles and statements by the New York Times over a period of 30 years illustrates the evolution of public perception of this topic. Various metrics were defined for quantifying hopes and fears, optimism and pessimism as well as other topics relating to the field of AI. It was found that the number of reports on AI has increased significantly since 2009. These are more optimistic than pessimistic, but the worries surrounding loss of control due to AI have increased, as have those relating to ethics and the possible negative effect of AI on the world of work. The greatest hopes are for healthcare and education (Fast, Horvitz, 2016).

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What societal effects can we expect from the increasing use of AI in all areas of life?

As a universal technology, like electrical power or the Internet, for example, AI will also radically change all areas of life and work and transform entire value-creation chains and societal structures. In spite of its enormous potential – especially as a solution to major challenges such as climate change – AI also poses substantial risks to society that we are not yet able to fully assess. We are faced with the dilemma that the societal and social effects of technologies are difficult to predict until they have reached full development and dissemination.

What are the ethical risks of using AI?

The ethical issues are numerous and relate, among other things, to the use of the data material on which the AI technologies are based. For example, there is currently a discussion under the term “datafication” about critical developments in how AI technologies breach our privacy and thus expose the deepest and most intimate aspects of ourselves.

This makes people vulnerable, because their wishes, needs and desires can be predicted and manipulated by means of targeted behaviour engineering, for example. Furthermore, there is the risk that stereotypes and prejudices about certain population groups in the data material used for the AI technology could be reproduced, which could ultimately lead to unfair and potentially politically motivated decisions. These developments therefore also result in the gradual restriction of human freedom and self-determination and thus inevitably raise questions about our understanding of democracy.

While China and the USA are fighting for AI supremacy with hard means, Europe is following an ethics-based approach. Do you think this can work?

Absolutely! In the context of rapid technological change, ethical considerations are indispensable if trust is to remain a central element of social, economic and political action in the future. The concept of a “trustworthy AI” that the European Commission can also get behind is the key to “responsible competitiveness”. Work should be done to ensure that all people affected by AI technologies can trust that these systems are conceived, developed and used in a lawful, ethical and robust manner.

China is using AI for its social credit system. How much potential does AI offer for totalitarian states? What societal risks are associated with this and could China’s ethical position threaten Europe?

In contrast to liberal states, in China there have been conscious efforts on the part of the regime to influence the political discourse on a personal level using the Internet and advanced surveillance technologies. The Chinese government is also drawing on AI technology to collate and use data both online and offline for their controversial social credit system, with the aim of suppressing behaviour that is critical of the regime by means of censorship. The associated risks for society are considerable, above all the threat to mental self-determination and health and the restriction of freedom of the individual in general by means of coercion and unjustified mass surveillance. China is an example of how new technologies can be explicitly misused for the political goals of an authoritarian state.

With regard to liberal state systems such as in Europe, I consider there to be more of a danger of our societal structures and thus also our political systems being subtly altered by dint of the market dominance of a handful of companies ("surveillance capitalism"). In Europe as well, algorithms are already determining to a large extent which information we receive and which products or services we want to buy.

Do you think that the use of AI creates more opportunities or more risks for society?

From a societal perspective, the increasing use of AI brings both opportunities and risks. For me, personally, the opportunities win out, provided that we manage to establish the idea of a trustworthy AI and at the same time counter the risks associated with AI – i.e. digital, physical and political security risks – in an appropriate and proportionate manner. In particular, AI systems can help us achieve the goals for sustainable development set by the United Nations. Moreover, such systems can also help us monitor indicators that measure progress in the fields of sustainability and social cohesion. In order to achieve this, AI systems must be geared towards people and guided by the principle that they serve humanity and the common good with a view to enhancing human welfare and freedom.

2 Regions under the microscope – the framework conditions for AI

2.1 Europe: the ethical AI approach

In comparison to other countries and regions of the world, Europe is characterised by a strong focus on the ethical and principled use of artificial intelligence. For example, in 2019, building on from the European Strategy for Artificial Intelligence, an expert commission appointed by the European Commission presented ethical guidelines for the development and use of trustworthy AI in the EU. These guidelines are above all aimed at ensuring that AI is used for the benefit of society by supporting human action and respect for fundamental rights. The importance of privacy and the sovereignty of citizens over their own data are also brought to the fore.

However, the strategies and the speed at which individual European countries are politically pushing ahead with the topic of AI vary. The leading AI nations are the United Kingdom, Germany, France and the Scandinavian countries, which all have their own distinct strategies for using and promoting AI.

2.1.1 Politics and society

In April 2018, the European Commission published their AI strategy, which above all puts people centre stage, is based on European values and thus follows an ethical approach. In order to boost Europe's competitiveness in the global AI market, the 28 member states of the European Union as well as Norway have committed to work together and have set the following goals:

- The use of AI should be expanded in the entire private and public sector by increasing technological and industrial capacity. Access to data and investments in research and development play an important role in this.
- In order to be prepared for the socioeconomic changes to come, such as the modification of job profiles in the professional world, education and training systems should be modernised and adapted. This includes retraining programmes for professionals, fostering digital skills in the MINT subjects and supporting partnerships in industry in order to attract and retain more AI talent.
- AI guidelines were developed in order to uphold the values of the European Union and establish the ethical framework. They are the result of a detailed analysis of the changing challenges faced by various stakeholders and the collaboration between them.

Roughly 1.5 billion EUR is to be invested in this between 2018 and 2020 within the scope of the research and innovation programme "Horizon 2020". When the contributions of the member states and those of the private sector are added together, investments within the EU are expected to increase to 7 billion EUR per year or a grand total of 20 billion EUR by 2020. Most of this funding will go into basic research and market-creating innovations. Aside from the creation of AI centres of excellence, small and medium-sized companies shall also be encouraged to apply AI technologies by making it easier for them to access these (EU Commission, 2018b).

Building on this first strategic plan, in December 2018 a coordinated plan of action was published as the strategic roadmap for the way ahead. The main goal is for all member states to devise national AI strategies based on European measures by mid-2019 (EC, 2018a). Some states have already published national AI strategies.

- **Germany**

500 million EUR has been earmarked for developing the AI strategy in 2019 and each subsequent year. This means that a total of around 3 billion EUR is to be made available by 2025 for the implementation of the strategy, with this sum subsequently doubling due to the leverage effect on the economy, science and federal states. In November 2018, the German government set out 12 areas of action for the future of AI, which in turn gave rise to 14 goals. In addition, numerous measures were proposed for achieving these goals.

Priority is given to three of these goals:

(I) Europe, and above all Germany, shall work to become a leading AI location in order to remain competitive in the future. In order to achieve this, a globally recognised German seal of quality "Artificial Intelligence (AI) made in Germany" shall be created. Germany shall become an attractive research, innovation and business location for artificial intelligence experts in Europe. With due regard to the data sovereignty of citizens, specific databases shall be made available for the purpose of creating AI-based business models.

(II) At the same time, AI shall be developed and used responsibly and for the benefit of the common good. It must be checked whether existing guidelines need to be amended in order to keep in step with applicable ethical and legal principles.

(III) Finally, AI shall be rooted in society, not only from an ethical standpoint but also from a legal, cultural and institutional perspective. Development shall be focused around people and the potential of AI shall be exploited for sustainable applications (BMBF, 2018b).

- **Finland**

In December 2017, Finland published the first report of the artificial intelligence programme, commissioned by the Finnish Ministry of Economic Affairs and Employment. It contains eight key steps for successfully implementing AI in Finland. These include increasing investments, using data more efficiently, supporting AI experts and creating new cooperation models (TEM, 2017). In June 2019, the final report of this AI programme was presented, supplemented by three additional key steps, which are in turn subdivided into measures already taken, lessons learned therefrom and recommendations for the future. It also contains a vision of where Finland is hoped to be by 2025 with regard to AI.

- **France**

On 29 March 2018, the French president Emmanuel Macron unveiled the national AI strategy based on the report by the French politician and mathematician Cédric Villani. It sets the following priorities:

By supporting experts and expanding the AI ecosystem, France shall become a more attractive location for international pioneers. To do this, a national AI programme coordinated by the National Institute for Research in Computer Science and Automation (Institut national de recherche en informatique et en automatique, INRIA) shall be set up and the number of students with knowledge of AI shall have doubled by the end of the 5-year plan. The synergies between public research and industry shall be strengthened in that researchers will now devote half of their time to private companies as opposed to 20%, as is currently the case. Furthermore, an open data policy shall be introduced for the use of AI in promising fields.

At the same time, however, a European framework for data use shall be developed in order to protect the privacy of users. Further down the line, an international group of AI experts shall be formed with a view to defining ethical guidelines in order to prepare the population for the digital transformation resulting from the use of AI.

In order to achieve these goals, the government wants to invest 1.5 billion EUR into the development of AI by the end of 2022, 700 million of which will go into research. This research shall focus on the fields of healthcare and mobility as well as environment and defence. It is hoped that fully automated driving, for example, will be permitted by 2022 in France (Villani et al, 2018).

- **Sweden**

In December 2017, the report "Artificial intelligence in Swedish business and society: Analysis of development and potential" was commissioned and subsequently published by the Swedish government. It showcases the possibilities of AI and prioritises important AI projects for Sweden. Among the AI fields mentioned in the report that are deemed especially important for the development of Swedish industry and for the population are: travel and transportation, sustainability and smart cities, health and safety and financial services (Vinnova, 2018).

In February 2019, the "National Approach to Artificial Intelligence" was published, which identifies the measures required in the eyes of the government in order to position Sweden at the forefront of AI development and use. According to the report, the most important prerequisites for this are strengthening the education and training sector, research, and innovation and application initiatives. Appropriate guidelines and a suitable infrastructure that should supplement those of the European Union would be required for each individual field (Näringsdepartementet, 2018).

For this purpose, the government has already invested 40 million SEK (~3.73 million EUR) in various universities in 2018 and 2019 so that they can train their AI experts. Sweden's innovation agency Vinnova, which wrote the report from 2017, has announced significant investments over the next 10 years. Moreover, the Swedish Digitalisation Minister Peter Eriksson has started an AI arena in Gothenburg, which is intended to promote collaboration between the various actors and to strengthen Swedish companies (FLI, 2018).

- **United Kingdom**

The "AI Sector Deal" was launched in March 2018 within the scope of the industrial strategy in collaboration with the Department for Business, Energy and Industrial Strategy (BEIS) and the Department for Digital, Culture, Media & Sport (DCMS) as well as the AI experts Dame Wendy Hall and Jérôme Pesenti. The most important political measures of this deal are divided into the five categories of ideas, people, infrastructure, business environment and places. Total R&D investments are expected to reach 2.4% of GDP by 2027.

In addition to the country's existing world-renowned higher education system, a prestigious technological education system shall also be created. To do this, 406 million GBP (~445 million EUR) shall be invested into training technical specialists in order to address the lack of MINT professionals, among other measures.

The infrastructure shall also be improved by means of investments into the charging network for electric vehicles and expanding the 5G network. Furthermore, in future there shall be more partnerships between industry and the government and measures for efficiently growing SMEs shall also be devised. Finally, transportation between cities shall be improved in order to forge stronger links between them (Clark et al, 2018).

The Select Committee on Artificial Intelligence set up in June 2017 presented a report entitled "AI in the UK: ready, willing and able?" in April 2018. The report admits to the fact that the United Kingdom cannot keep up with China or the USA when it comes to investment volume and personnel resources, but recommends concentrating on the ethical aspects of AI in order to create a competitive advantage. Moreover, an "AI Code" consisting of five principles has been proposed by the British government:

(1) AI should be developed for the common good and benefit of humanity. (2) AI should operate on principles of intelligibility and fairness. (3) AI should not be used to diminish the data rights or privacy of individuals, families or communities. (4) All citizens have the right to be educated to enable them to flourish mentally, emotionally and economically alongside artificial intelligence. (5) The autonomous power to hurt, destroy or deceive human beings should never be vested in artificial intelligence (Select Committee on Artificial Intelligence, 2018).

In June 2018, the government took up position and implemented many of the plans and recommendations from the report (DEBEIS, 2018).

In addition, Lithuania published its AI strategy "A Vision of the Future" in April 2019. Russia is currently working on a national R&D AI strategy. The Irish government has already held numerous AI workshops and launched a national AI master programme. In March 2019, Spain presented an AI research, development and innovation strategy. The Agency for Digital Italy has appointed an interdisciplinary AI task force. In Austria, the Council on Robotics and Artificial Intelligence is working on a national AI strategy. Denmark already has a digital strategy, which includes AI among other technologies as a focal point (FLI, 2019).

Societal acceptance of AI in Europe

In March 2017, a survey of 28,000 EU citizens was conducted on behalf of the European Union in order to gauge public opinion on the influence of digitalisation and automation on daily life. The topic of robotics and AI was also included, and 81% of those surveyed have a positive opinion of it. 68% believe that robots and AI are beneficial to society. Fundamentally, those who have heard or read about AI or have had experiences with it within the last 12 months view the technical development more positively. The greatest concerns relate to the work of world. Many of those surveyed fear that AI will replace more jobs than it will create. More than one third would use a robot during work or for ordering products, but a significantly smaller proportion would agree to their use in medical procedures or geriatric care. Overall, however, 88% of survey participants believe that a great deal of caution should be exercised when researching and developing these technologies (EC, 2017).

2.1.2 Research and technology

In Europe, there are various transnational organisations that deal with research into AI and its development. One of these is the Confederation of Laboratories for Artificial Intelligence Research in Europe (CLAIRE), an initiative with the aim of creating an alliance of AI research laboratories with a "brand awareness" similar to that of the European Organisation for Nuclear Research CERN. Numerous research institutes and scientists have already joined this initiative. For this reason, the founders want to set up a CLAIRE hub in order to facilitate the flow of knowledge into the home institutions of the participating scientists. In so doing, they consider it important to promote trustworthy AI and to involve the entire European population (CLAIRE, 2019).

The initiative European Laboratory for Learning and Intelligent Systems (ELLIS) primarily aims to make Europe a leading AI location through technological collaboration. In order to achieve this, the actors are currently pursuing two paths: firstly, becoming the best at basic AI research in Europe and, secondly, creating jobs and gaining economic influence through research, regardless of the interests of industry. They are therefore working closely with CLAIRE and assist each other in their relevant projects. The goal is to strengthen cooperation between countries through measures such as establishing international training programmes or research laboratories (ELLIS, 2019).

The European Association for Artificial Intelligence (EurAI) serves as an umbrella organisation for numerous national AI societies and departments specialising in AI (Winter, 2019).

Looking at the distribution of AI laboratories throughout Europe, France, the United Kingdom, Germany and Spain clearly dominate with 50% combined. France is in the lead, with 21% of all European AI laboratories, or a total of 82. What is also worth noting is that 70% of all laboratories in the top 4 countries mentioned are located in publicly funded schools and universities. The following four thematic groups are particularly prominent: technology, financial services, entertainment/media/culture and healthcare/biotechnology. In addition, there are twelve other countries, especially in Northern Europe and in the Baltic region, that are becoming more and more influential and are catching up with the top 4 (Bouée, Bioulac, 2018).

- **Germany**

The AI map on the platform “Learning Systems”[5] shows the 110 scientific institutes and institutions currently operating in Germany. Of these, 44 deal with basic research, 47 with image recognition and interpretation, 48 with data management and analysis, 46 with human-machine interaction and assistance systems, 30 with robotics and autonomous systems, 33 with sensors and communication, 18 with speech and text comprehension, 35 with changes to processes and production, 14 with virtual and augmented reality, 20 with societal effects and 12 with legal and ethical issues. The map for example shows the new AI centres of excellence in Berlin, Munich, Dresden/Leipzig, Dortmund/Bonn and Tübingen funded by the Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung, BMBF) as part of the artificial intelligence strategy as well as the German Research Centre for Artificial Intelligence (Deutsche Forschungszentrum für Künstliche Intelligenz, DFKI) founded in 1988.

The DFKI is the most important research organisation for software-based AI in Germany. It is divided into 19 research areas and groups, each with 8 centres of excellence and so-called living labs. Product functions, prototypes and patentable solutions are developed in these facilities proceeding from application-oriented basic research. In total, more than 1,000 scientists, administrative staff and student employees from more than 65 nations are working on over 250 projects at the DFKI (Karger, 2019).

The Fraunhofer Society, the Max-Planck Society and the Helmholz Association are also of great importance for AI research in Germany.

In order to entrench artificial intelligence in universities as well, 100 additional new professorships will be advertised (FAZ, 2018). And newly offered courses at universities also signal that significant progress is being made with regard to training new specialists for German AI research.

[5] Platform by acatech – German Academy of Science and Engineering, see www.plattform-lernende-systeme.de.

At the Beuth University of Applied Sciences in Berlin, students can now study "Humanoid Robotics", and alongside the interdisciplinary Master's programme "Robotics, Cognition, Intelligence" at the Technical University of Munich, the Munich School of Robotics and Machine Intelligence (MSRM) has been founded, which is conducting interdisciplinary research into the fields of healthcare and mobility (Schareika, 2019). Furthermore, individual countries in Europe are also trying to cooperate with one another more closely at the research level. For example, France and Germany are planning a Franco-German AI research network. They also intend to make mobility and the exchange of teachers and researchers easier (BMBF, 2018a).

- **France**

In a press release published in November 2018, the Ministry for Higher Education, Research and Innovation (MESRI) presented current AI figures for France: As it stands, there are 5,000 scientists, 250 research groups and 35 Master's programmes that focus on AI (Schlütter, 2018). In the same month, the national AI research strategy – which builds on the AI strategy of the French government – was presented and the government's 665 million EUR budget was released. Together with the 358 million EUR of funds from research organisations, companies and the European Union, this gives a total budget of over 1 billion EUR (ibid.).

A research programme coordinated by the INRIA national research institute was set up in 2019 within the scope of the national AI research strategy. The following four new AI research institutes – known as 3IA for short – have been created for this purpose, and INRIA is involved in the first three: in Grenoble the MIAI@Grenoble-Alpes with a focus on health, environment and energy, in Nice-Sophia Antipolis the 3IA Côte d'Azur with a focus on health and spatial development, in Paris the PaRis Artificial Intelligence Research InstitutE (PRAIRIE) with a focus on health, transport and environment, and in Toulouse the Artificial and Natural Intelligence Toulouse Institute (ANITI) with a focus on transport, environment and health.

The National Investment Council has set three research priorities as development targets of the first published AI research strategy plan: AI and medicine, AI and security, and cybersecurity (Schlütter, 2019).

Furthermore, the institute DataIA – which hosts more than 130 researchers in the application fields of mobility, optimised energy policy and urbanisation and boasting a budget of 400 million EUR – was founded as part of the programme "Investments for the Future" of the French National Research Agency (Agence nationale de la recherche, ANR),

Research personnel and funding

From 2019, in addition to the 3IA research institutes, 40 new AI professorships are to be advertised nationally and internationally and the number of AI postgraduates – currently 250 – is to be doubled. In 2018, funding worth 27 million EUR was provided by the ANR for 61 projects, and over the next few years another 100 million EUR is to be set aside for AI research projects. Furthermore, scientists shall spend 50% instead of 20% of their practical working time at companies in future (Schlütter, 2018).

More cooperation

In total, the French government and companies are to invest 65 million EUR in different research organisations that want to build bridges between research and industry in their work. This is the case, for example, for the ANR programme LabCom, which financially supports SMEs and research institutes when setting up a joint research laboratory, or the application-oriented Carnot institutes, which conduct research in collaboration with industry. Bilateral European partnerships shall also be bolstered, above all cooperation with the German government.

To this end, there shall be an annual call for proposals for a research project with a budget of 3 million EUR and synergies shall be leveraged through joint platform and data use. By 2022, a total of 115 million EUR is to be spent on Franco-German AI cooperation (ibid.).

- **United Kingdom**

For the United Kingdom, artificial intelligence is an important part of its industrial strategy. As such, in 2015, the Alan Turing Institute was founded using state resources and with the participation of various universities, including Oxford and Cambridge. Its main sphere of activity is AI research. Although the founders initially concentrated on national projects during the first two years, in future they also hope to be internationally active. They consider there to be eight fields of application of AI in R&D. For example, they intend to revolutionise healthcare and to design algorithms systems in a fair, transparent and ethical manner (The Alan Turing Institute, 2019).

Another institution composed of several universities is the Leverhulme Centre for the Future of Intelligence (CFI). Here, the universities of Cambridge and Oxford are working with Imperial College London and the Berkeley University of California. They define their goal as follows: to bring together the best of human intelligence so that we can make the most of machine intelligence (CFI, 2019).

The Centre for Governance of AI at Oxford University wants to help promote the benefits of AI for humanity and to minimise the risks it poses. They focus on the political challenges associated with the transformation of the industrial sector through the use of AI. According to them, these changes could be just as profound as the Industrial Revolution (FHI, 2019).

Aside from the AI research and development programmes of the big players – Germany, France and the United Kingdom – other countries are also striving to put Europe in a leading position in the AI race. In the Czech Republic, the privately funded research project Good AI, which was launched in 2014, focuses on the humanitarian and ethical aspects of AI. Over 30 scientists, engineers and advisers are working in the three teams Good AI Research, Good AI Applied and Good AI Digital. The first of these teams tackles research issues such as drawing up an ordered list of requirements for an AI to reach the level of human intelligence, the second deals with specific applications in industry, and the third is dedicated to the development of a chatbot[6] for the Czech and Slovak languages (GoodAI, 2019).

The Nordic Artificial Intelligence Institute (NAII) in Stockholm is a non-profit union of international experts on AI and related topics. They provide strategic advice for companies and government institutions, organise workshops, training courses and conferences, promote AI R&D and support start-ups in the field of AI (NAII, 2019).

Technological status quo

According to the Global Connectivity Index (GCI) developed by Huawei and conceived for analysing the IT infrastructure of individual nations, European states appear seven times in the top 10 of 79 nations analysed in 2018. Sweden is the best European country in 3rd place, whereas Germany only makes the top 20 in the 14th position. Data generation and data transfer via broadband in particular are considered as important foundations for AI development.

[6] Digital dialogue system with natural language abilities.

With regard to availability of 4th generation (4G) mobile Internet, only four European countries out of a total of 87 nations have secured a place in the top 10. Those with excellent 4G coverage in Europe include Norway at 95.5% as well as the Netherlands (92.8%), Hungary (91.4%) and Sweden (91.1%) (Boyland, 2019).

The United Kingdom is an example of what can be achieved with initiatives. Tireless political efforts to interconnect and expand digital services have helped put the United Kingdom in the top 5 of the GCI. The intensive implementation of 4G, the coverage rate of which increased from 27 to 77% within four years to 2018, has resulted in radical improvements to the country's IT infrastructure. Moreover, investments into the Internet of Things (IoT) were more than doubled within the same space of time from 200 to 441 USD per person, which in turn boosted data generation. At the same time, the number of IoT devices installed grew from four to ten connections per person, which shows that the IoT strategy of the government – which is hoped will bring more IoT technologies and services into the public and industrial sector – has borne its first fruits. There are also plans to further expand the 5G network (HUAWEI, 2018).

In the global race for the hardware technology required for developing AI, Europe is lagging far behind and relies on the USA and China for powerful AI chips. Meanwhile, these two countries are the only nations in the world that are manufacturing so-called Graphic Processing Units (GPUs). These GPUs are used to handle the gargantuan quantities of data required for training AI. Although Europe already has chip manufacturers, most notably in the Netherlands (NXP Semiconductors N.V., STMicroelectronics N.V.) and the United Kingdom (ARM Ltd., Imagination Ltd.), they cannot keep up with American hardware providers such as Nvidia or Google, which are already offering the required hardware via cloud models (Harhoff et al, 2018).

The picture is similar with regard to the availability of supercomputers. Supercomputers, or high-powered computer systems (HPC), require AI to train algorithms, process colossal amounts of data and learn from past events and make decisions. Europe has 96 of these computers, which puts it behind China (220) and the USA (116). Within Europe, France comes out on top with 20 supercomputers, followed by England (18), Germany and Ireland (both 13) (Dongarra et al, 2019).

But when it comes to IT infrastructure, Ireland in particular is making great progress, especially in the expansion of data centres and cloud services. In this regard, Europe overall is performing very well – with 1,186 data centres at approximately 700 million Europeans, it is much better equipped than China (97 centres), with the United Kingdom (247), Germany (194) and France (147) making up the core. But with 2,432 providers, the USA steals the crown globally (Data Center Map ApS, 2019).

Findings regarding the quality of the publicly available government data measured using the Open Data Barometer show the enormous potential for Europe. Based on the availability of data from the health sector of environmental statistics, for example, the European members of the G20 are on average at the same level as the USA with 66.5 out of 100 points. The United Kingdom achieved the highest score in the entire sample with 79 points, far ahead of China at the bottom of the pile with a score of just 31. Nevertheless, the lack of a comprehensive, European data pool remains a major obstacle (World Wide Web Foundation, 2017).

Open Data Barometer	USA	China	UK	France	Germany	Italy
	64,00	31,00	76,00	72,00	68,00	50,00

Table 2: Readiness and implementation progress for open data initiatives and programmes (World Wide Web Foundation, 2017).

Supercom-puters	USA	China	Europe	UK	France	Germany	Italy	Finland	Ireland
	116	220	96	18	20	13	5	2	13

Table 3: Top 500 supercomputers (Dongarra et al, 2019).

Data centres	USA	China	Europe	UK	France	Germany	Ireland	Nether-lands
	2.432	79	1.186	247	147	194	22	100

Table 4: Data centres (Data Center Map ApS, 2019).

2.1.3 Economy

Economic implications

The ability within Europe to exploit the full potential of artificial intelligence is very different in individual member states. The differences in the economic and technological resources as a basis for rapidly developing key technologies are particularly striking between the less developed eastern and southern European member states and the stronger northern and western European countries. Nevertheless, overall European GDP could grow cumulatively by 19% by 2030 thanks to AI, which translates to an additional 2.7 quadrillion EUR on top of the existing 13.5 quadrillion EUR (Bughin et al, 2019). Above all, the wider variety of products that AI would bring would stimulate consumption in the European market, and in Germany, for example, it would generate an additional 430 billion EUR – thus boosting GDP by around 11% by 2030 (Kirschniak, 2017).

Although jobs have generally been lost over the last 15 years as a result of new technologies, AI technology promises to be a positive development in this regard. Experts predict that 11 million jobs could be created by 2030, but work profiles will change radically. In future, more and more routine tasks, mostly in middle-class sectors, will be performed using the automated processes that come with AI, whereas the demand for highly qualified employees with high cognitive and social skills will increase. Employees with a low or medium level of education will be most at risk of losing their jobs as a result of technological progress. In Ireland, for example, it is estimated that 38% of tasks of employees with a low level of education will become automated (Barnard Roberts et al, 2018).

In a comparison of the automation potential of European industries, Europe is on par with the USA at 37%, with significantly higher rates in eastern European countries (Slovakia 44%) and lower rates, for example, in Finland (22%). Automation will have a greater impact on jobs in production and construction, but less so in the education sector (ibid.).

Fundamentally, Europe has the potential for rapid technological development, but as a general rule seems to be falling short of its full potential. When compared with 45 selected countries across the world, Europe excels in the use of information and communication technologies thanks to a high capacity for innovation, high Pisa values and good automation rates. However, Europe urgently needs to address shortcomings in certain fields, i.e. the AI ecosystem or AI start-ups per capita, R&D expenditure and the development of business models in the field of information and communication technology (ICT) (Bughin et al, 2019).

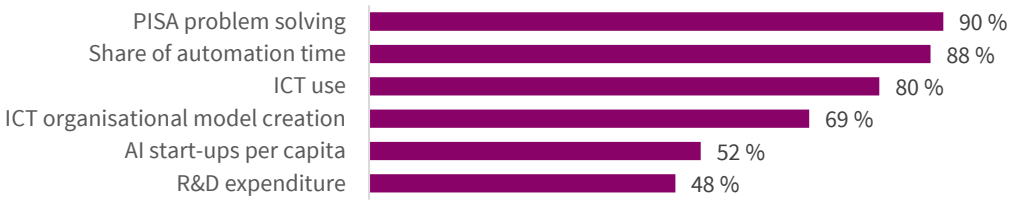

Figure 7: AI enablers[7] (own graphic based on Bughin et al, 2019).

This is particularly evident in the ICT sector – although European economic clout is comparable to that of the USA and somewhat above that of China, the digital and AI-based share of the European ICT sector amounts to just 1.7% of gross domestic product, with the Scandinavian countries Finland (3.0%) and Sweden (2.8%) leading Europe. The European average thus corresponds to approximately half of the US share (3.3%) and also comes out lower than that of China (2.2%). In order to catch up with the two leaders China and the USA, Europe must minimise regional differences. If it can do this, an additional 900 billion EUR would be generated by 2030 (ibid.).

Ecosystem of AI companies

As already mentioned, the AI ecosystem is a potential obstacle to European AI development. Although Europe has a total of 769 AI start-ups, a figure which has tripled between 2011 and 2016, in absolute values it is behind the USA in second place. Furthermore, the majority of these start-ups are concentrated in the major tech centres of the United Kingdom (245), France (109) and Germany (106), where the focus is on robotics, Internet of Things and self-driving vehicles. The average proportion of European companies that have already integrated AI into their business models is 4.6%, well below that of the USA (8.2%). In Sweden, which is one of the most digitalised countries in the world, this figure is 7.2% (Bughin et al, 2019).

If you compare the European AI scene with that of Silicon Valley, for example, in which talent, capital and research is concentrated into an area of roughly 200 km^2, the strong fragmentation in Europe becomes glaringly obvious. The most important European tech hubs of Paris, London, Berlin and Helsinki, which have the most AI start-ups, are on average about 1,000 km from one another as the crow flies. Nevertheless, Europe performs strongly when it comes to AI research, with London being the largest tech innovation centre in Europe with growth capital to the tune of 3.4 billion USD. In other words, investments into London's tech hub are three times higher than that of Paris, Berlin and Tel Aviv combined (QUID, 2018).

In cooperation with 13 British universities, the national Alan Turing Institute in London acts as a cross-interface link between research, industry and politics in the fields of data sciences and artificial intelligence, with a focus on game theory, neural networks, pattern recognition and robotics (The Alan Turing Institute, 2019).

[7] 100% corresponds to the maximum value of all 45 countries analysed.

With 73 AI start-ups, Paris is the second largest European hub and is working intensively to forge closer ties between industry and research with the publication of its AI strategy. Then there is the German Cyber Valley in the Stuttgart-Tübingen area of Baden-Württemberg, which aims to become a world-leading graduate school over the coming years with more than 100 postgraduates in the fields of machine learning, robotics and computer vision. It wants to become a hub in itself with key actors from science and industry from around the world by providing a link between four research institutes and eleven partners from industry (e.g. Amazon, Daimler AG, etc.) (Williams, 2019).

In Germany, two internationally renowned institutes, together with the DFKI and the Fraunhofer Institute for Intelligent Analysis and Information Systems (IAIS), are building up the ecosystem for actors who are researching and working on the use of artificial intelligence. Being in one of the first countries in Europe to have a fully-fledged AI strategy, Helsinki is the fourth largest AI ecosystem. The universities of Aalto and Helsinki are working with the VTT Technical Research Centre of Finland to foster long-term basic research and short-term application-oriented AI research in constant consultation and knowledge transfer with companies, politicians and students (Aalto University et al, 2019).

As large digital corporations such as GAFA in the USA or BAT (Baidu, Alibaba and Tencent) in China are lacking in Europe, a joint European research initiative needs to be created in order for the continent to keep up with the competition, and this has already been included as one of the goals of the European Commission's AI strategy.

Investments and M&A

The lack of strong European tech corporations is particularly damaging to European AI start-ups when it comes to investments and mergers and acquisitions and is reflected in the relatively low level of investment in AI, totalling 3.6 billion EUR to date, with a maximum individual amount of 90.5 million EUR. Moreover, due to the more short-term oriented (less than 5 years) investments made by the mostly risk-averse private investors, average initial funding for AI start-ups comes to just 3 million EUR in France and 2 million EUR in Germany. With the exception of public subsidies and European venture capital – which has stagnated at a share of 11% since 2016 – Europe, much to the advantage of international competition, lacks stronger levers and the willingness to hand out substantial funding on the Chinese scale, which averages 32.6 billion EUR.

This investment gap would be even larger if it were not for the strong activity in the United Kingdom. English start-ups, which are buoyed up by big venture capital investors such as the hardware and software developer Graphcore, can achieve quadruple growth thanks to total funding over five years – including record sums in 2018 of 1.2 billion EUR, compared with 398 million EUR in France and 272 million EUR in Germany (Daws, 2019).

With the launch of an EU programme for venture financing, the European Commission in collaboration with the European Investment Bank is trying to provide a boost to the overall sluggish development. The VentureEU fund, which is currently valued at 400 million EUR and which should eventually total 2.1 billion EUR, can force European investment into AI start-ups (Bughin et al, 2019).

Talent situation

Europe is doing fairly well compared with the rest of the world when it comes to AI talent. With top universities in Germany, France and Switzerland, there is a solid basis for computer sciences and AI. This is especially clear if you consider the current situation of companies that employ AI specialists.

With Siemens (176 specialists, 4th place), SAP (58 specialists, 13th place) and Bosch (56 specialists, 14th place), three European corporations make it into the top 20 employers of AI specialists in the world – four companies from the USA appear in this list, but only one from China. Europe is ahead of the USA when it comes to software developers, in particular, with 5.7 million experts compared with 4.4 million in the States and an annual growth rate of 10%. Between 2016 and 2017, the number of software developers in Germany increased by 18% to 850,000, followed by the United Kingdom with 830,000 experts in this field. However, it should be noted that Europe-wide growth rates among developers have dropped to around 5% in the last two years.

In order for Europe to keep up with technological developments, it must remain a highly attractive location for new talent. As part of the changes to job profiles already mentioned above, there will be a strong increase in demand for talent from the tech field, and therefore there will be a greater need for skilled workers. The increase in demand will likely be 41% in Germany and 66% in Spain. The European Commission estimates that, across Europe, 500,000 new ICT experts will be required within the next 5 years. Although Europe is lagging far behind other parts of the world when it comes to graduates in the MINT subjects, higher growth rates can be expected here in the future – with an increase in the number of MINT postgraduates of 50% within a decade (Bughin et al, 2019).

2.2 USA: The fight for AI supremacy

With world-leading digital corporations such as Google, Apple, Facebook and Amazon, the USA appears to be in a very good position when it comes to AI. This is confirmed by a study by the Center for Data Innovation published in autumn 2019, which investigated the AI activities of the USA, China and the EU (Castro, 2019). The study looked at the categories of talent, research, development, application, data and hardware. The results suggest that, overall, the USA is on top and occupies first place in four of the six categories. However, China is quickly catching up thanks to an AI initiative of the government, among other things.

2.2.1 Politics and society

Strategic plan of the Obama administration

In 2015, the US government invested approximately 1.1 billion USD into researching and developing AI-relevant technologies. In order to tap the full potential of this sum, an initial AI strategy was then devised in 2016 under the Obama administration. The main aim of this “National AI R&D Strategic Plan”, implemented by the National Science and Technology Council (NSTC), was to explore the long-term impacts of AI and prioritise fields that industry was not likely to address as much as others (NSTC, 2016).

White House Summit on Artificial Intelligence for American Industry

It has a taken a while for US president Donald Trump to come up with a concrete AI strategy. In May 2018, during the White House Summit on Artificial Intelligence for American Industry, a general outline of the government’s approach for promoting AI was set out, but no documented national strategy was presented. The main declarations of intent of this meeting were to strengthen the national ecosystem for AI in order to foster public-private partnerships and to speed up research and development in this context. Furthermore, American employees shall be prepared for the jobs of the future in order to exploit the full potential of AI for industry. This includes an increased focus on MINT subjects from the start of a child’s school career as well as technical training, retraining and lifelong learning programmes that will be adapted to the needs of industry.

It was also considered important to break down barriers to innovation in order to secure the USA's leading position. In addition, the importance of informing the public about AI so that they have a better understanding of these novel technologies and their benefits for daily life was highlighted. Finally, those who attended the meeting considered it essential to facilitate implementation of sector-specific AI applications (White House, 2018).

American AI Initiative

On 11 February 2019, the Trump government launched the so-called American AI Initiative by executive order. It comprises five main core areas:

- **Investment in AI research and development**

Here the focus is on prioritising AI investment within the R&D activities of federal authorities. It is hoped that this will strengthen the American R&D ecosystem of industry, government and research and yield AI innovations that directly benefit the American population.

- **Better accessibility of AI resources**

This initiative calls on state institutions and agencies to make official data, models and computing resources easier to access for AI experts, scientists and industries, while also preserving data security, data protection, civil rights and privacy.

- **Developing AI guidelines**

By drawing up cross-industrially applicable guidelines for AI research, federal agencies hope to increase public trust in AI applications. Furthermore, suitable technological standards are to be defined in conjunction with the National Institute of Standards and Technology (NIST) in the interest of developing AI systems that are more reliable, more robust and more trustworthy.

- **Preparing the job market for the AI revolution**

In order to provide the American population with the skills required for a professional world shaped by AI, more and more research grants and training programmes are to be offered in the field of computer sciences and other MINT subjects. This should help to train more employees for research and development in the field of AI in order to be equipped for the introduction of new AI technologies.

- **International AI cooperation while maintaining the country's competitive AI advantage**

This initiative aims to create an international environment for AI R&D and open markets for the American AI industry. At the same time, the technology should be developed in a manner that upholds the values and serves the interests of the USA. Additionally, the federal authorities shall devise an action plan for protecting the strategic advantage of the USA in the AI sector and concealing associated confidential information from competitors (White House, 2019).

Although AI actors have been instructed to prioritise AI-related research projects, the state will not provide them with any additional financial support. The aforementioned goals may be ambitious, but they have been worded rather vaguely. Furthermore, it is unclear to what extent they follow on from the strategic AI plan drawn up under the Obama administration (Andriole, 2019).

In June 2019, an official update was issued by the NSTC, which had made various changes and updates in collaboration with numerous AI experts, research institutes, companies and civil society since publication of the strategic plan in 2016. The amendments primarily focus on application-oriented sectors such as manufacturing, healthcare, cybersecurity, education, natural sciences and climate research. Ethical aspects and issues relating to responsibility and transparency of AI systems are also taken into consideration to a greater extent (NSTC, 2019).

Societal acceptance of AI

Americans have a mixed opinion of AI, its development and the effects it could have on society, but the majority are fundamentally in favour of the technology. In a study conducted by Oxford University in June 2018, roughly 2,000 Americans were surveyed and 41% indicated that they are strongly or somewhat in favour of the development of AI, while 22% are fundamentally opposed. Demographic aspects also appear to be relevant here: Generally speaking, participants with a university degree, those with a higher household income and/or those with experience in IT or programming tended to have a positive opinion on the matter. Topics such as data security and privacy protection were considered to have a particularly large impact on the population and were therefore deemed to be the most important issues to deal with. Moreover, it was considered important to prevent cyberattacks or the dissemination of false or damaging content using AI. In principle, Americans seem to have the greatest trust in researchers at universities and in the military when it comes to the development of AI (Zhang, Dafoe, 2019).

2.2.2 Research and technology

While many activities in the field of research and development take place within the private sector in the USA, the focus of policy is on the federal authorities (e.g. the Department of Commerce, Department of Energy and Department of Defense) as well as the National Science Foundation (NSF) and the Intelligence Advanced Research Project Activity (IARPA) (Groth, 2018a).

One of the most successful research measures of the government authorities is the DARPA. In September 2018, several years' worth of investment totalling more than 2 billion USD was secured for existing and new AI projects within the scope of the so-called AI Next Campaign. The focus of this campaign is on AI that offers new development opportunities and that is robust and effective. DARPA is pursuing the vision of not only using AI as a tool in future, but also creating a symbiosis between human and machine. For this purpose, they are working on – as they call it – the "third wave" of AI. The "first wave" is considered to be the rules-based AI and "second wave" the statistical learning-based AI. Another funding programme of DARPA is Artificial Intelligence Exploration (AIE), in which high-risk projects that would nonetheless yield high profits if successful are funded over a period of 18 months (DARPA, 2018).

Other important research institutes are the Machine Intelligence Research Institute (MIRI), which was founded as the Singularity Institute for Artificial Intelligence in 2000, the Stanford AI Lab (SAIL) at Stanford University, the Future Of Life Institute based in Cambridge, Massachusetts, the AI Now Institute of New York University, and the Allen Institute for AI (AI2).

Among other things, MIRI focuses on the possible risks associated with super-intelligent machines that could in future be used not for the benefit but to the detriment of humanity. For this purpose, the scientists have defined six research areas in which it could in future be easier to develop and implement artificial superintelligence (MIRI, 2019).

SAIL, which has been operating since 1962, is a centre for research and teaching in the field of artificial intelligence. It is divided into the core research areas of machine learning, natural language processing, computer vision, robotics, health and autonomous driving. The summer programme Stanford AI4ALL aims to give young people from disadvantaged population groups the opportunity to explore the topic of AI (SAIL, 2019).

The Future of Life Institute is an alliance of scientists and public figures such as Elon Musk and Morgan Freeman who have set the primary goal of keeping AI developments beneficial for humanity (FLI, 2019).

The AI Now Institute deals with the social impacts of AI and thereby focuses on the fields of rights and liberties, labour and automation, bias and inclusion, and safety and critical infrastructure (AI Now, 2019).

As a research institute, AI2 deals with the development of learning, reading and thinking AI systems, with the aim of contributing to the development of AI that is geared towards the common good (Schoenick, 2019).

Technological status quo

The USA is one of the most advanced nations on the planet when it comes to connectivity, computing power and availability of cloud services, which in addition to data generation are essential parameters for the development of AI. With regard to IT infrastructure, in particular, the USA enjoys a solid lead ahead of other nations – in the GCI, it comes out on top out of a total of 79 countries (HUAWEI, 2018). This is not least due to the extensive expansion of the fixed broadband network, which reaches 94% of all households with an average download speed of 25.86 Mbit/s (Kruger, Gilroy, 2019).

With regard to data storage, the USA for example has ten times more data centres than the United Kingdom, the former having a total of 2,432 such centres (7.43 per 100,000 inhabitants) and the latter having just 247 (3.72 per 100,000 inhabitants) (Data Center Map ApS, 2019). The North American market for intelligent sensors that can be used to collect data has grown from 140 billion to approximately 330 billion USD within the space of four years, while the European market – which is also growing fast – is predicted to go from a current value of 171 billion USD to 241 billion USD by 2022 (Kalal, 2019).

Moreover, the approximately 240 million Internet users are a valuable source of data, with the United States only falling short of China and India – which have far bigger populations – when it comes to the number of Internet users. Measured in terms of absolute population size, the USA has a higher coverage than these two Asian giants at 88.5% (Jones, 2018). In addition to the national stockpile, there is also the potential pool of the huge American tech corporations, of which Facebook alone has an enormous data pool with more than 2 billion hits per month (Groth, 2018a). Taken together, this produces an immense treasure trove of data for training AI algorithms.

Another indispensable element for a strong AI ecosystem is access to the required hardware, which is at the centre of a fierce global competition and even a trade embargo. Huge datasets that can only be processed using powerful chips known as GPUs are required for the increasingly popular deep learning method and for training its neural networks. In contrast to conventional processors, these chips can process quadrillions of matrix calculations in parallel. Even though the competition from Chinese tech companies is heating up, Nvidia, Google, AMD and fast.ai from the USA are currently dominating the global chip manufacturing market (Harhoff et al, 2018).

Furthermore, Google, for example, is offering its machine learning software TensorFlow for AI developers free via the cloud such that they can take advantage of the network effects created by this for themselves and retain clients far into the future (Greenman, 2018).

Better chips necessarily require better computers – with 116 supercomputers, the USA currently has the second highest computing power in the world (Dongarra et al, 2019). Although there is an immense amount of data available in the United States, there is room for improvement when it comes to the quality and availability of public sector data – in this regard, the USA is behind the United Kingdom and France on the Open Data Barometer, ranking in 3rd place with 64.00 points (Web Foundation, 2018).

2.2.3 Economy

Economic implications

With regard to gross value added – which can approximately be used to express GDP – according to an Accenture study of 12 developed countries that together generate 50% of the world's economic output, the USA stands to benefit the most economically from the use of AI as a production factor. According to this study, the economy could grow by 4.6% per year until 2035 if AI applications are factored in, which is well above the 2.6% calculated on the basis of current benchmarks excluding AI (Accenture, 2017).

However, the increasing automation of production processes will radically transform many industrial professions. According to estimates by the auditing firm PwC, 38% of all jobs in the USA will be impacted by automation processes. This applies, in particular, to jobs with manual and repetitive tasks from the sectors of production (53%), wholesale and retail (51%) and construction (34%). Across all sectors, there appear to be few differences between the genders: 37% of jobs carried out by women and 39% of posts occupied by men will be affected by increasing automation.

However, significant differences are expected with regard to level of education; 46 and 47% of those with a medium and low level of education, respectively, will see changes to their work, whereas only about 21% of those with a higher level of education will face changes (Barnard Roberts et al, 2018).

Ecosystem of AI companies

The maturity of the AI ecosystem in the USA is as of yet unrivalled, with American AI companies being able to grow within a highly sophisticated network of research institutes, investors and talent. Silicon Valley is a prominent example of this, and is considered around the world to be the epitome of innovation centres, with the perfect biotope for exchange between research, application and investment flourishing here around San Francisco Bay since the 1950s. Stanford University with its SAIL laboratory is considered to be a pioneer in the field of artificial intelligence and, together with Berkeley University, is an important AI talent pipeline for the GAFA hi-tech big players headquartered in the area. Furthermore, other major corporations such as Nvidia, which leads the way in the manufacture of AI chips, and Tesla, a leader in the field of autonomous driving, have their head office in the high-tech hub in San Francisco. Silicon Valley also dominates the world start-up market, with more than 110 billion USD of venture capital and private funding. 41% of all global AI investments flow into companies from this small area of California (Synced, 2017).

The role of Silicon Valley as a perfect breeding ground is particularly evident in a comparison of the top 20 largest tech hubs in the world, with San Francisco coming out on top with 596 AI start-ups (ahead of London with 211 AI start-ups). The strength of the USA cannot only be attributed to the enormous tech hub of San Francisco, the USA has a total of five other regions in the top 20. One of these is the New York/Boston zone on the Eastern Seaboard, which includes the Massachusetts Institute of Technology (MIT), which is another excellent university in the AI sector with a strong focus on application thanks to the Watson AI Lab – a research facility it runs in cooperation with IBM. The close connection between American universities and industry fosters the numerous university projects that sometimes morph into fully fledged companies.

The USA also dominates in terms of AI companies. Of a world total of 4,998 registered companies that have integrated AI into their business model, 40% are American firms (CAICT, 2018), and the number is increasing. It is estimated that 52% of all US companies will have integrated AI as a technological advancement into their corporate practice by 2030. The USA also leads the way when it comes to AI start-ups, with a total of 1,393 (40% of all worldwide AI start-ups), far ahead of China in second place, which has 383 AI start-ups (Asgard Capital et al, 2018). In addition, five of the largest tech giants – Facebook, Amazon, Microsoft, Google and Apple – are based in the USA, which provides the perfect platform for the development and implementation of AI. For example, Google invested 20 billion USD in AI in 2016 and Microsoft alone acquired five AI tech firms by 2018 (Kukushkina, 2019).

Investments and M&A

The USA is the world leader when it comes to investments and mergers and acquisitions, which can above all be attributed to the exceptionally high levels of activity from the tech giants based there. Taken together, the GAFA companies bought up nearly 40 AI start-ups between 2010 and 2018. While only 4 billion USD was invested in AI in Europe in 2016, that figure was 23 billion USD in the USA (Asgard Capital et al, 2018). For example, Google acquired the AI start-up DeepMind for 400 million USD in 2016.

Although the total number of deals in the USA fell for the first time in 4 years in 2018 (from 553 to 466), American AI companies boasted a record 9.3 billion USD in revenue for the same year (CBInsights, 2018). This corresponds to an increase of 72% compared with 2017, or roughly 5.4 billion USD. In 2018, the USA ranked second behind China in terms of private investments, accounting for 38% of such activity in the world, which equates to a volume of 570 million USD.

Talent situation

The current talent situation in the USA can be classified as critical if you consider that there are currently only 235,000 data specialists out of a total of 150 million people in employment. With roughly 580,000 MINT graduates, the USA ranks third in the world, far behind India (2.6 million) and China (4.7 million). The US government is trying to counteract the current trend with a targeted campaign for skilled workers, which is expected to produce 10,000 Master's graduates and doctoral students in the field of AI research per year. Nevertheless, big American corporations have a great deal of pulling power, with most AI talent being drawn to companies such as IBM (538 specialists), Microsoft (341) and Google (256). This puts the USA at the head of the top 20 list of countries that have recruited the most AI specialists (Tsinghua University, 2018).

2.3 China: the data deluge

Whereas in Europe data protection and user privacy is of utmost importance, China is drowning in data. From a technical perspective, this provides optimal conditions for developing AI applications. However, in view of the Chinese social points system, in which citizens are monitored by the state using digital technologies, the societal risks of AI are laid bare.

The Chinese government has recognised the importance of AI to the development of the country and is pursuing the strategic goal of becoming the leading AI nation by 2030.

2.3.1 Politics and society

In July 2017, China published a highly ambitious and detailed AI strategy plan, which – if implemented successfully – would not only solidify China's prominent position within the field of AI, but would catapult the country far ahead of all other nations, including the USA. The strategic objective of the so-called New Generation Artificial Intelligence Development Plan is divided into three steps.

- **Catch up with the West by 2020**

China intends to make significant progress towards a new generation of AI theories and technologies by 2020. This involves creating an industry worth over 150 billion RMB (~19 billion EUR) for AI and over 1 trillion RMB (~126.5 billion EUR) for related branches of business.

- **Make breakthroughs in AI by 2025**

The technological feats the government hopes to achieve by 2025 should help to secure the country's status as a world leader. At the same time, the monetary value of the industry is hoped to exceed 400 billion RMB (~50.5 billion EUR) for AI and over 5 trillion RMB (~632 billion EUR) for related branches of business.

- **Become world leader in AI by 2030**

China hopes to bring about numerous pioneering innovations as the world's primary AI innovation centre. Additionally, the AI industry should have reached a value of 1 trillion RMB (~126.5 billion EUR) and related industries should have attained a value of 10 trillion RMB (~1.27 trillion EUR) (State Council of the People's Republic of China, 2017).

In December 2017, half a year after the strategic plan was published, the Chinese Ministry for Industry and Information Technology (MIIT) launched a detailed 3-year action plan, which sounds relatively ambitious. This plan, which is to be realised between 2018 and 2020, focuses on four areas of activity:

- In order to pave the way for the first breakthroughs, clear targets have been set for eight fields of application – including facial recognition, AI-assisted medical diagnosis and autonomous driving.
- Another goal seen as indispensable in the New Generation Artificial Intelligence Development Plan is to develop powerful AI chips as a solid basis for further development.
- AI is also expected to play a more important role in industrial and manufacturing processes in future.
- Finally, large datasets and other resources required for training AI applications shall also be provided.

Other measures were also introduced in parallel with this action plan. In October 2017, the MIIT invited tenders for 13 AI technology projects that are to be realised by 2021 primarily using state funding. One of the aims is to develop a more powerful AI chip. In November 2017, the major companies Baidu, Alibaba, Tencent and iFlytek became part of the National AI Team, which aims to promote AI in the fields prioritised by industry and the government. An example of an industry favoured in this context is autonomous driving. In January 2018, plans to build an AI campus comprising 400 companies in Beijing were made public. Furthermore, it was announced that the AI guidelines of the comprehensive strategy "China Standard 2035" were being drawn up (Bieri et al, 2018).

Societal acceptance of AI

In general, there is a high level of acceptance in China for novel technologies such as AI. The Chinese are keen to try them out if they will make their daily lives safer and more comfortable, with data protection and privacy protection taking more of a back seat. This general acceptance opens up a wealth of application opportunities. For example, in a school in Southern China, the faces of pupils are scanned in the canteen such that the food ordered by individual pupils can be dispensed correctly. Pupils' faces are also scanned during lessons in order to find out who is concentrating (Dorloff, 2019).

The generally high interest in AI was evidenced, for example, in 2016, when the greatest increase to date in Baidu search requests on the topic of artificial intelligence was recorded after a game of the traditional Chinese strategy game Go was won by Google DeepMind's AlphaGo against the world's then best player Lee Sedol (Ding, 2018).

2.3.2 Research and technology

Research from the Allen Institute for AI over recent years showed that although China publishes a lot on the topic of AI, the quality is still somewhat lower than that of the USA, for example – but that changed in 2019. Such was the finding of the Semantic Scholar project, in which more than 2 million scientific articles were analysed. The citation rate was used as one of the criteria for classifying the quality of an article. The results show an upward trend in the proportion of Chinese publications among those that are cited most frequently, whereas fewer and fewer of those coming out of the USA are being cited (Schoenick, 2019).

Aside from evaluating the quality of publications, the amount of data and the quality thereof are also critical factors for winning the race for AI supremacy. The amount of data available in China makes it easier for companies and research organisations there to test and use new technologies. For example, the camera density is many times higher than in the USA and above all compared with Europe (Dorloff, 2019).

In China, the focus is on cooperation between government, companies and academic institutions. With regard to the development of AI, in particular, the focus is on the national Military-Civil Fusion strategy unveiled in 2013, which is intended to blur the boundaries between civil and military resources. This approach could serve China very well, as government and industry would harness synergies rather than diverging down different research paths (Bieri et al, 2018).

In order to counteract the lack of researchers in China, numerous scientists were given funding between 2009 and 2011 within the scope of the Thousand Talents Program, but some empirical studies from different countries around the world stated that the expertise of these scientists was not universally outstanding. Many Chinese companies are now trying to bring scientists back into China via AI research centres set up abroad. In order to ensure a sufficient number of AI experts in the country in the long run, China is also planning to set up AI institutes and a wide variety of AI study programmes (Ding, 2018). As it stands, most AI researchers come directly from universities and research organisations (Tsinghua University, 2018).

China has recently become the country with the most AI patents filed worldwide. The majority of these patents concentrate on data processing systems and the transformation of digital information, with those relating to image processing and analysis making up 16% of the total. In 2017, the focus of the entire Chinese AI market was on computer vision, speech recognition and natural language processing. AI has already been applied in the fields of healthcare, finances, education and security, in particular (ibid.).

Overall, China's research landscape appears to be profoundly shaped by companies and by institutions set up by these companies. At the same time, there is a great deal of collaboration with foreign universities and with the offices of Chinese firms aboard. For example, in 2017, Alibaba founded the Alibaba DAMO Academy (Academy for Discovery, Adventure, Momentum and Outlook), with three sites in the USA, one in Israel, one in Singapore and two in China, where research is being conducted into the subfields of machine intelligence, data processing, robotics and financial technologies. (Alibaba Group Holding Limited, 2019). The Chinese Internet corporation Baidu operates two research and development laboratories in Silicon Valley in the USA. One of these deals above all with topics such as self-driving cars and cybersecurity, while the other works in the fields of artificial intelligence and data centres (Bloomberg, 2017).

Tencent AI Lab, founded in April 2016 by the Internet company Tencent, conducts AI research at its first research laboratory in Seattle into the fields of computer vision, speech recognition, natural language processing and machine learning for the company's four key business areas Social, Game, Content and Platform.

Technological status quo

In the GCI, which gauges countries' IT infrastructure, the People's Republic of China has recorded the largest growth in some areas, which can almost certainly be attributed to China's long-term development strategy for the digital transformation.

The massive sums of money invested into the high-speed Internet technology 4G have resulted in an enormous increase in coverage of the population – from 7% in 2014 to 69% in 2017. Within the same timeframe, domestic fibre optic coverage grew by 46% to 64% in 2017. The increasing expansion of the fixed and mobile broadband network in China is continuously driving the growth of e-commerce and is therefore making it easier for small and medium-sized Internet companies to take root. With regard to AI, China has invested large sums into data centres, cloud services, big data and IoT as the basis for its smart city initiative and now boasts almost 50% of all smart cities in the world (HUAWEI, 2018).

With regard to the availability and quality of public data, China comes in last place among the nations compared here. Nevertheless, the People's Republic has access to an enormous data pool in the private sector, thanks, on the hand, to its 730 million Internet users and, on the other hand, to its own large technology corporations: For example, China's answer to Facebook – WeChat – is accessed one billion times per month. Furthermore, the collection of data required for training the AI algorithms is structured in a simpler manner than in Europe, for example, where data is subject to stricter rules and regulations (Groth, 2018a).

Another important factor in China's meteoric rise in the field of AI is the availability of supercomputers, with the People's Republic having 220 of the 500 supercomputers in the world, thus putting it in 1st place (Dongarra et al, 2019). However, one area in which there is significant room for improvement is the production of the required AI chips, as standard processors cannot achieve the required computing speeds. This is compounded by the ban imposed by the US government on exports of American chips to China, for which the Chinese government is seeking to compensate by building up their own chip industry using a specially created fund worth 47 billion USD (Arnold, 2018).

2.3.3 Economy

Economic implications

The use of artificial intelligence has immense economic significance for China. Even based on conservative estimates, studies indicate that GDP growth could accelerate by 20% until 2030 thanks to AI, which puts it 6% above the global average. Taking gross value added into account, cumulative growth over the period between 2017 and 2030 is even expected to reach 38% (Hawksworth et al, 2017). However, extremely strong growth is not the only thing China can expect. According to a study by Oxford University, 77% of existing jobs are threatened by advancing automation, which is the highest value among all countries examined, with the exception of Ethiopia (Frey, Osborne, 2017).

But the risk sinks to 39% if only task types as opposed to rigidly defined professions are considered (Hawksworth et al, 2017). The professions that will be most greatly affected over the next 20 years are in the fields of industry, in which 35% of all jobs will be ripe for substitution, as well as agriculture and construction, where 27% and 25% of jobs, respectively, will be lost. Nevertheless, thanks to increased economic growth, it is predicted that 300 million new jobs will be created, thus more than making up for the 200 million jobs lost. According to these calculations, China will gain a net 12% new jobs through AI over the next 20 years, and only the agricultural sector could face a loss of 22 million jobs (ibid.).

Ecosystem of AI companies

With regard to the domestic corporate landscape, China can undoubtedly be counted as one of the fastest growing countries in the world. With a total of 4,925 companies operating worldwide using AI components, China ranks second with over 1,000 companies, which dominate the AI market in the fields of computer vision (34.9%), speech recognition (24.8%), computer linguistics (21%), hardware (11.3%) and algorithms (8%) (Tsinghua University, 2018). China's journey to the top is also reflected in the number of young companies, which – totalling 383 – represent 11% of all start-ups worldwide and have access to 48% of all private equity financing (Hawksworth et al, 2017).

Additionally, the cooperation between the digital behemoths Baidu, Ali Baba and Tencent (BAT) and the Chinese state as well as China's metropolises, which dole out large sums of money to AI firms, provide ideal conditions for AI developments to flourish. Firstly, the large BAT corporations can provide access to comprehensive datasets that are required for training the algorithms. Moreover, they can continuously push major investments in the latest data technologies and, at the same time, are very attractive to young talent from around the world. Secondly, the density of AI firms in China is already very high. With the metropolises of Beijing, Shanghai, Shenzhen and Hangzhou, China is represented four times in the top 20 metropolises with the most AI firms, with Beijing having the largest concentration of AI firms in the world – more, even, than San Francisco – with a total of 395. This abundance of AI firms increases interconnectivity and boosts the size of the market (Tsinghua University, 2018). And, finally, young companies are benefiting from state protectionism, which allows domestic firms to innovate while being shielded from foreign competition.

The region of Zhongguancun in the north-west of Beijing can be considered the most important innovation centre, as it is home to roughly 9,000 hi-tech companies – including Baidu and Sina Corp – and has been the focal point of research, investment and commercialisation in China for 30 years. The AI sector alone obtained 7.6 billion USD of investment (China.org.cn, 2019). Furthermore, Beijing's two leading universities, Beida and Tsinghua – which have specialised in basic research into core AI and AI hardware in close collaboration with industry – are AI talent factories.

This in turn lures large multinational corporations such as Microsoft or Intel, which are driving the innovation process further forward by founding their own research institutes. As per China's AI strategy plan, this process is to be accelerated by the construction of a technology park worth 2.1 billion USD, which shall be built in Beijing within the next 5 years in cooperation with Google (Kharpal, 2018).

The city of Shenzhen, which houses the headquarters of the tech giant Tencent as well as numerous renowned universities, is also of great significance, with its focus being more on the application of AI technologies. Thanks to its dense manufacturing network, which is capable of providing a complete supply chain for the AI industry, Shenzhen is known as the "Hardware Capital of the World" and also receives special funding from the government due to its status as a "Special Economic Zone". And with its lively start-up scene, sustained by a strong financial centre for cross-sector private investments, it is considered to be a burgeoning innovation centre in the field of robotics, in particular – the city's production value of humanoid and industrial robots was already 11.4 billion USD in 2016 (He, 2017).

In addition to its up-and-coming innovation hubs, China's broad market structures in the field of intelligent systems also reaffirm its position as a major contender.

It is no coincidence that the Chinese market for industrial robots has been the largest in the world since 2013 with over 138,000 sold and is significantly larger than that of the USA, which is in fourth place with 33,000 machines sold. In addition, Chinese companies can boast a market share of 27% in the global intelligent loudspeaker market, which is growing at an astonishing rate. Only Google and Amazon are in front with 3.2 million (36.2%) and 2.5 million (27.7%) speakers sold, respectively. Fundamentally, however, China is increasingly shifting away from merely copying products to manufacturing its own and setting its own "Made in China" standards (Tsinghua University, 2018).

Investments and M&A

Investment activities in China have experienced an enormous upsurge since 2016 and have placed the People's Republic ahead of the USA in terms of global investments in AI start-ups. Of the total 15.2 billion USD, 48% now flows into Chinese AI start-ups (compared to 11% in 2016), with an average of 36 million USD per fundraising deal (whereas, in the USA, this figure is just 10 million USD) (Bughin et al., 2018). Furthermore, young companies are benefiting from the close links to the Chinese government, which wants to invest 59.1 billion USD in domestic industry within the next six years (Asgard Capital et al, 2018).

Public funding for companies such as CloudWalk and Megvii, which use AI for digital facial recognition, amounts to 301 million USD (CloudWalk) and 460 million USD (Megvii), and together with the start-up SenseTime is exemplary of increasingly large-scale financing with a value of over 100 million USD. Across the board, a hive of activity can be observed around AI technology for facial recognition purposes. The number of funding deals in this sector has grown from 11 to 41 within the space of a year, and this can be presumed to be part of the central government's "Xue Lang" (English: "eagle eyes") strategy, which aims to install surveillance cameras in public and private spaces up and down the country. Fundamentally, high investment volumes can be observed in the People's Republic, and only early stage investments have been decreasing since 2014, although this could point to more rational investment activities if series A funding remains stable (CBInsights, 2018).

Talent situation

With regard to the overall situation regarding artificial intelligence experts, China is most definitely on the advance across all sectors – the world's largest pool of MINT graduates (4.7 million) and qualified AI scientists (300,000; incl. students) provides a solid basis. However, examining the situation more closely and looking at the number of AI specialists currently available, it is clear that China still has a lot of work to do, which would necessitate further investments in (foreign) experts. According to a report by the Tsinghua University on the current status quo of AI, the USA has roughly 65% more AI experts than China, with over 28,000 (13.9% of the global talent pool) in the former and roughly 18,000 (8.9% of the global talent pool) in the latter. This is also evidenced by the distribution of AI talent in companies, with Huawei being the only Chinese company to feature in the top 20 list of companies in the world with AI experts (Tsinghua University, 2018).

2.4 Israel: the start-up nation

With an average of 140 newly founded start-ups per year over the last five years, Israel leads the world in per capita terms and is rightfully touted as the "Start-Up Nation". The Israeli government identified the founding boom early on and took political measures to create a suitable ecosystem for start-ups and investors. In the field of AI, Israel boasts the second highest number of start-ups – and that number is growing rapidly.

2.4.1 Politics and society

While the USA and China are competing with one another for AI supremacy and Europe is trying to join in, Israel is also on the road to becoming an AI nation. In 2017, Israeli AI start-ups raised almost 2 billion USD – 70% more than in 2016 (Press, 2018). However, the country still lacks a fully-fledged national strategy. It is likely that the beginnings of an ecosystem that makes it easier for AI innovations to take root were already established due to the successful business ideas in Israel, above all in the start-up sector, over the last two decades. However, the IIA fears that Israel could be left behind if it fails to come up with such a strategy. In its innovation report from 2018, the IIA therefore calls on government, industry and research to work together on an AI strategy for the Israeli economy. Although market-oriented innovations have in many cases received funding due to their economic competitiveness, AI developments are often technologies that are distant from the market. Therefore, intervention on the part of the government is required. The IIA therefore recommends a strategy that addresses the following key challenges:

- Improving the research infrastructure in the field of AI and expanding Israeli research universities to AI centres of excellence
- Supporting skilled staff from data science experts to experienced AI scientists with suitable incentives and appropriate remuneration
- Developing an R&D infrastructure for use by industry and research while protecting privacy and maintaining transparency
- Introducing AI technology into all relevant sectors (Gabay et al, 2018)

New regulations from the government are also aimed at fostering AI research, among other things. For example, since 2016, selected high-tech companies have only had to pay 6 or 12% corporation tax instead of 25% (Chikorel, Blau, 2019).

Societal acceptance of AI

Surveys on the perception of AI in the Israeli population are lacking, but the high density of AI start-ups shows an interest and pervading innovative spirit among the Israeli people. The Internet usage rate of 74.7% in December 2014 is one of the basic prerequisites for the use of AI applications by consumers. And when it comes to applying AI, a special focus is given to implementation in the education and health sector (Getz, Goldberg, 2019).

2.4.2 Research and technology

The technological infrastructure department of the IIA is responsible, among other things, for providing an R&D infrastructure and the knowledge transfer from the academic world into industry. For this purpose, the MAGNET consortium, for example, was set up, which provides support for projects from industry and research over a period of three years (Gabay et al, 2018).

Between 2006 and 2012, the Israeli Ministry of Education noted a constant decline in the number of mathematics students and a stagnation in the number of MINT students. Moreover, there was a large discrepancy between rural areas and cities as well as between men and women. In order to tackle this problem and to train the required experts for AI research, the National Program for the Promotion of Math and Science was launched, which aims to bring more students into the MINT subjects, in particular mathematics (ibid.).

In order to secure the future of Israeli education with regard to technology and AI, in particular, universities shall in future offer online courses on the international platform edX, which was created by Harvard University and MIT. In addition, start-up and innovation centres shall be set up at universities, with the aim of imparting relevant knowledge to students for the research and development of novel technologies such as AI and to support them in projects of social and/or economic significance. It is hoped that these innovation centres will transform the universities into ecosystems that foster creativity, minimise obstacles and provide a link between research and industry (ibid.).

Technological status quo

When it comes to the interplay of data availability and data generation required for AI development, Israel still appears to be lagging behind. The country has a population of 8.38 million, nine data centres for collecting data and ten cloud service providers. This puts the country in 54th position in terms of the density of data centres (Cloudscene, 2019). The Open Data Barometer also suggests that there is room for improvement, with Israel being placed 28th and thus providing only moderate access to public data (Groth, 2018b).

This contrasts with an extensive IT infrastructure, with Internet access for roughly 75% of the population. With an average Internet speed of 13.1 Mbit/s, Israel is behind the USA (18.7 Mbit/s) and Germany (15.3 Mbit/s), for example, but when it comes to top speed, the country has the advantage over these two nations with a maximum of 99.1 Mbit/s (USA: 86.5 Mbit/s, Germany: 65.6 Mbit/s). This puts Israel in 9th place in the world (Belson, 2017).

The fact that Israel currently has none of the top 500 supercomputers could put it at a strategic disadvantage to its competitors in the struggle for AI supremacy. Nevertheless, the country has a chipmaker in its ranks in the form of Mellanox, which, after being bought up by the American manufacturer Nvidia, supplies more than half of all supercomputers with power (Halon, 2019). The picture is similar for the IoT, which may not be very widely used, but the dynamic start-up ecosystem harbours internationally coveted expertise in IoT, cloud computing and chip manufacture (Bloching et al, 2016).

2.4.3 Economy

Ecosystem of AI companies

Israel has one of the most flourishing and upwardly mobile ecosystems for young, interdisciplinary companies that often work at the interface between a variety of technological fields. With an average of 140 companies founded per year over the last five years and a tripling of the annual growth of AI firms within the last four years, it is with good reason that Israel is nicknamed the "Start-Up Nation". According to data from the Israel Venture Capital Research Center, this puts the total number of start-ups that actively develop and/or apply AI technologies at 954. It also places Israel second in the world when it comes to number of AI start-ups (Scheer, 2019).

The close links between incubators, working spaces for knowledge exchange and investor acquisition as well as politics and research is a crucial factor in the success of Israeli companies. Israel's answer to America's Silicon Valley is the Silicon Wadi (from the Arabic wadin = valley) – consisting of the exurbs between Tel Aviv, Haifa and Jerusalem – and is one of the most successful technology centres in the world, with more than 6,500 start-ups, 300 high-tech companies and the high-tech share of exported industrial goods standing at 45%. One of the reasons for this high density of start-ups is the hugely favourable subsidy climate for tech firms, which, if they raise 15% of their funds by their own means, can be sure of receiving the remaining 85% from the state. As AI is also considered to be the technological basis for the 4th Industrial Revolution by the government, companies with AI components are given preferential treatment when it comes to funding (IHK Nord, 2018).

Furthermore, Israeli universities make a significant contribution to AI with close links to industry. The start-up Mobileye, which spans off from the Hebrew University and which had given the university a pioneering position in intelligent driving systems, was sold to Intel for 15.3 billion USD, a record price for an Israeli start-up. On top of this are research tasks of the military at the University of Tel Aviv and technology institute Technion in Haifa, which are continuously driving applied research forward (Scheer, 2019).

According to estimates by Asgard Capital and the management consultancy firm Roland Berger, Israel comes third in the world with 362 AI start-ups, which is impressive considering the size of the country. The majority (71%) of Israeli start-ups offer software-based AI solutions that focus on business-to-business and marketing (Singer, 2018). In line with the global trend, 51% of business models are based on machine learning methods, of which 21% use the deep learning method and 13% work with computer vision, but fewer deal with robotics (4%) and speech recognition (3%) (ibid.). 44% of AI start-ups are already generating annual sales of up to 10 million USD and 6% are recording even higher figures (Scheer, 2019).

Moreover, the trend is moving away from foreign takeovers in the early stages and towards establishing oneself as an independent company. What is remarkable here is that seven unicorns have already been able to develop in Israel, of which four start-ups were funded with deals of over 100 million USD (ibid.). A solid financing base is of fundamental importance for young companies, since they have to compete with the likes of China and the USA from the very start. These start-ups are supported in this by incentivising policies and strong incubators.

Last but not least, the military and the Israeli secret service Mossad are also important pull factors: With the help of the Libertad Ventures fund, Mossad is aiming to strike up partnerships worth 2 million ILS (~500,000 EUR) with start-ups in the fields of cyber, computer linguistics and robotics (ibid.).

Investments and M&A

In spite of the growing trend towards the emancipation of companies, corporate takeovers play a major role in Israel, or at least they did so in the past. For example, in 2014, Apple invested 350 million USD in PrimeSense, a manufacturer of hardware and chips for three-dimensional computer vision technology. Four years later, the company Datorama was acquired by Salesforce, which offered them 800 million USD (Scheer, 2019). And, of course, there was the sale of Mobileye – a world-leading provider of advanced driver assistance systems – to Intel in 2017, which was the biggest deal in Israeli tech industry history with proceeds of 15.3 billion USD, cementing Israel's status as a key global AI region for the automotive sector (Lunden, 2017).

At the same time, the high growth potential of Israeli tech firms not only attracts a swarm of external buyers, the increasing number of investor deals also testify to the growing interest and trust in the Israeli AI start-up squad. 2017 marked the high point of investment deals in Israel, with 207 contracts signed. This is also reflected in the amount of funding, which climbed 70% compared with 2016 to 1.94 billion USD (Singer, 2018). Firms with AI technology, in particular, seem to draw the most interest from investors – 80% of venture capital investor funds went into companies whose business model has an AI component, the majority of this in the first two funding rounds. This can also be seen in private investment that flows into AI components from Israel, which accounts for 4% of global private participation. With this value, Israel is ranked third behind the USA and the United Kingdom (ibid.).

Talent situation

As with the other nations reviewed here, Israel does not appear able to keep up with the rapid development of AI either. This is manifested in the lack of well-trained experts such as programmers and engineers, with a shortage of approximately 10,000 specialists. Nevertheless, Israel is considered a hotbed for AI talent thanks to its dynamic ecosystem. This is reflected in industry, with 64% of Israeli AI experts working for start-ups and 31% in multinational corporations with AI centres and labs in Israel (Singer, 2018). Intel (280 AI specialists) and IBM (130) have the most AI experts, then come the labs of Amazon (70), Apple Israel (65), Google AI Research Center and Microsoft (both 50) (Scheer, 2019).

Furthermore, roughly 650 Master's students per year graduate with a broad knowledge of AI technologies in Israel, and a significantly higher number of specialist staff can be expected in the future, as there has been an increase in applications for computer sciences with a focus on artificial intelligence. In the MINT subjects, which are relevant to AI, an increase of 4,000 to 11,000 Bachelor degree applicants is expected over the next six years due to more substantial grants and, in the case of Master's and PhD degrees, the number of graduates increased from 2017 to 2018 by 50% from 60 to 90 (ibid.). The proportion of women among currently enrolled PhD students stands at 30% (Singer, 2018).

3 Implications for the integrated energy transition

3.1 The energy transition in national AI strategies

Looking at the different approaches taken by the countries and regions examined in this report, four key points emerge that play a consistently important role in their respective AI strategies and that have decisive implications for the energy industry:

- An emphasis on education and training programmes is vital for achieving the national AI R&D goals. In the context of the digital transformation of the energy system, in particular, the various actors can be divided into two camps – those with expertise in the field of digitalisation and those with an in-depth knowledge of the energy industry. In future, it will become increasingly important to combine these skills, for example in new university courses.
- Increased cooperation between companies, start-ups and universities should ensure that the strengths of the relevant actors are identified and synergies utilised in order to drive AI forward. Especially when it comes to the field of energy, there is a large number of start-ups that are developing innovative solutions for the energy transition. Nevertheless, they often lack resources, which large companies could then bring in within the scope of collaborative efforts. Additionally, there are research institutes at universities, which often provide a different route into AI R&D than the private sector and as a result also deliver significant added value for joint projects.
- The speed of progress in the field of AI will not be fast enough for a full energy transition if the technical and industrial performance capacity of components required for AI is not improved. Therefore, developing powerful AI chips or boosting computing power is just as important for the energy industry as it is for other sectors.
- Although there is no standard or unambiguous definition of ethical AI, it is mentioned in the majority of AI strategies. This aspect is almost certainly less relevant to the energy industry than it is to medicine or mobility, for example. Nevertheless, the handling and publication of data is a frequently discussed key factor in the European energy industry, and one which could ultimately result in an AI technology not being implemented despite its potential.

When it comes to using this technology for the energy transition, although it is mentioned in many national AI strategies, it is often relegated behind sectors such as defence or healthcare. In the AI strategy of the **German government**, reference is explicitly made to the potential of AI for achieving the 17 Sustainable Development Goals (SDGs) of the United Nations. In order to devise criteria for evaluating the environmental effects of AI as a basis for establishing environmentally-friendly AI applications, an environmental data cloud shall firstly be created in order to provide transparency for industry, science and society. Furthermore, 50 lighthouse projects are being supported in order to harness AI to protect the climate, the environment and resources (BMBF, 2018b). The Environmental Digital Agenda published in March 2020 also clearly recognises the tremendous importance of climate protection and digitalisation and the potential to consider these two issues together (BMU, 2020).

The **Finnish government** has unveiled various sector-specific strategies, inter alia for generating climate-friendly energy using AI (Groth, 2018b). Due to its technologically very advanced energy system, Finland is considered to be a pioneer in the use of AI in the energy sector and as an attractive location for establishing field projects in this area (TEM, 2017).

Although the possible applications of AI in the energy sector are not mentioned explicitly in the AI strategy of the **United Kingdom**, these two fields of development have individually been identified as the greatest challenges of the future by the English government. Examining the Clean Growth Strategy more closely, a close relationship between both topics becomes apparent (Demetry, 2017). In the construction sector, which accounts for 40% of energy demand in the United Kingdom, the aim is to reduce overall energy needs by 2030 with the help of intelligent technologies and thus contribute towards the country's climate goals. For this purpose, a Construction Innovation Hub with funding totalling 72 million GBP has already been launched in order to support research during the development and commercialisation of digital technologies (BEIS, 2019).

France's AI strategy, which is based on the so-called Villani Report from 2018, cites the environment sector as one of the four main fields of application for AI, but the use of AI in the energy transition is not addressed in any greater detail. However, the report highlights the danger of high energy consumption by digital technologies and calls for energy-optimised AI, e.g. through energy-efficient use of the heat generated by data centres (Villani et al, 2018).

In the **USA**, the topics of energy and healthcare were reintroduced into the 2019 budget, but with the focus still very much being on defence and security as well as economic development (White House, 2019).

In the **United Arab Emirates (UAE)**, AI technologies are a central pillar of the country's strategic approach and in the development of new business areas. Artificial intelligence is to be used in nine different sectors, with a particular focus on renewable energies (asset management and smart energy consumption) as well as on the environment sector (afforestation) (Dubai FDI, 2018).

Research: energy as an integral part of the AI strategy

In terms of national AI strategies, the United Arab Emirates stands out as a shining example. In 2018, in close collaboration with the International Renewable Energy Agency (IRENA) and the Khalifa University for Science and Technology (KUST) and with the impetus of the Ministry for Climate Change and Environment, the **AI Lab for Renewable Energies** was set up with the aim of testing AI technologies for solar power and air pollution. They want to break new ground and thus take on a leading role in the implementation of targeted AI development compared with other state institutions, with a particular focus on the energy sector as a fundamental building block of the national AI strategy. For example, they want to use solar maps and simulations to determine the most suitable locations within the country for the construction of PV plants. Furthermore, they aim to use predictions regarding air quality to create an environment monitoring system for land and water. And by evaluating satellite images from NASA, they hope to identify oil leaks and water pollution early on (Enviromena, 2018).

South Korea views renewable energies, along with other domains such as autonomous driving, as one of the central fields of application of AI and plans to provide corresponding funding.

In **Japan's** AI strategy from 2017, the emphasis is squarely on the topics of productivity, the health system and mobility. In addition to using robotics in production, another important aspect of boosting productivity is to use AI to balance supply and demand in the energy system.

For this purpose, in the first of three phases, they hope to promote the application and use of data-controlled AI. In phase 2, AI applications and data shall be made public. In phase 3, an ecosystem shall be created by linking various sectors (MIC, 2017).

3.2 Artificial intelligence in the energy sector

Opportunities for the energy industry

Numerous application examples show that the energy industry benefits most from artificial intelligence through increased system efficiency, reduced costs and optimised decision-making. Therefore, this technology makes it possible to coordinate the transition to safe and climate-friendly power generation from renewable energy sources. In light of the increasing complexity of the energy system – which is a result of greater decentralisation of stakeholders and assets, among other factors – digital technologies of the 4th Industrial Revolution, including AI and IoT, will prove essential for a resilient, sustainable and affordable global energy supply.

The nine fields of application identified in the above-mentioned dena analysis "Artificial Intelligence for the Integrated Energy Transition"[8], which are divided into three clusters ("General Foundations for Decision-Making", "Maintenance & Security", "Distribution & Consumer Services")[9], make it clear that AI technology has tremendous potential – both today and in the future – for applications along the entire value creation chain of the energy industry: from generation to transportation and trade to consumption. According to a dena investigation of 150 organisations around the world[10] (including research institutes, start-ups/SMEs and large corporations) that are applying AI in the energy sector or are researching into its use, clear priority areas can be identified according to specific fields of application. According to this report, AI is currently being used overwhelmingly for operation optimisation and predictions (both cluster 1) and for predictive maintenance (cluster 2). In total, 95% of actors investigated operate within these fields. According to current research, other fields of application are rarely used to such an extent.

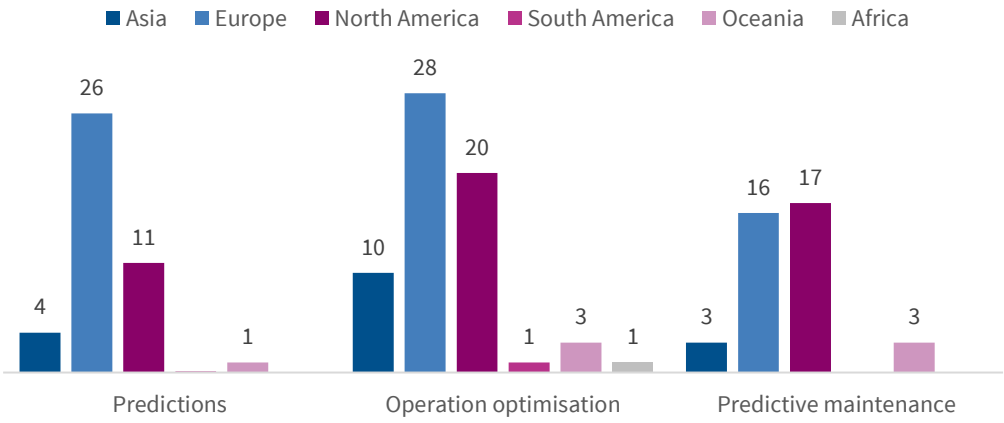

Figure 8: The fields of application of AI in an international context (own graphic).

[8] For more information, see the dena analysis "Artificial Intelligence for the Integrated Energy Transition".

[9] Detailed breakdown of cluster elements: Cluster 1: Inventory optimisation and other strategic business decisions, Making it easier for active consumers to participate; Cluster 2: Maintenance, repair and dismantling, Security measures; Cluster 3: Customisation of products and marketing measures, Process automation for measurements, bills and general distribution.

[10] The data given reflects the current status of ongoing research into current AI activities in the energy industry. The research primarily focuses on English-language online publications. We therefore make no claims as to the completeness or representativeness of the data. For more details, please visit www.dena.de/ki.

Just over one quarter (27%) of the 150 actors investigated use AI applications for predictions. This means that **Field of application 1 – Predictions** is the second most common area of use for AI. In Europe, in particular, predictions are a popular field of application – 26 of a total of 42 organisations active in this field come from Europe. This could be down to the relatively large number of weather-dependent power generation plants in Europe. Due to the growing proportion of renewable energies in the energy mix, the need for flexibility mechanisms will increase in order to compensate for fluctuations and ensure optimal capacity utilisation and reliability of supply in the power grid. Using the machine learning method, anomalies can be predicted by evaluating larger amounts of data from satellite images or measuring stations and thus adjusted perfectly to the consumption behaviour of clients, which ultimately saves operating costs.

Example: Impala Imbalance software from Optimeering

The goal of the Norwegian company Optimeering is to foster a sustainable and interactive energy system using AI that predicts likely power consumption using an intelligent software and monitors and controls future power production. Since power production via decentralised power plants such as wind and solar plants greatly depends on weather fluctuations, AI-based prediction can help to prevent inefficiencies in renewable energy generation. The machine learning algorithm used here was specifically designed for network operators and power producers to reduce the costs of imbalances in real time and increase yields. In addition, the Engine monitors energy markets (Optimeering AS, 2018).

The **Field of application 2 – Operation optimisation** based on AI is the most common of those included in dena's international actor analysis. 42% of all organisations investigated – of which approximately half are in Europe – are developing predictive strategies for the operation of energy-related assets using AI to analyse data available in real time (e.g. via the grid status, energy price developments or key power plant data). This approach ensures greater transparency in the market places and can help to identify critical grid conditions. Especially with regard to constantly emerging new applications such as electromobility, the respective battery-specific requirements such as the determination of charging and discharging times can be planned more efficiently by using AI, as in this way a multitude of secondary conditions can be taken into account.

Example: AI Diagnostics System DeepSolar from Raycatch

The DeepSolar software from the Israeli tech start-up Raycatch uses an AI-based technology to maximise the yield from solar plants. With the help of AI, colossal sets of data can be identified and analysed in an automated manner, which can be utilised for error diagnosis across all panels of a solar farm without the need for additional hardware or manual labour. The software measures the performance of the client's sensors and cleans up the data, for example to eliminate the distortive effects of temperature, dust, pollen and shade. The optimised data is then correlated with physical and electrical models and the results are processed using the AI algorithm in order to produce a complete analysis report about the solar plant. The software's precise error diagnosis (e.g. orientation to the sun, temperatures, poor coating or microcracks) helps with the time-saving and money-saving process of prioritising problems. In this way, the profitability can be quantified and increased for solar plant operators, costs can be reduced and power output can be improved. In addition, AI can be used to create task lists in an automated manner and in real-time and forward said task lists as instructions to technicians (Raycatch, 2019).

The anticipatory, intelligent planning of maintenance work on power-generation facilities, grouped under **Field of application 4** in the dena analysis – **Predictive maintenance** – is an important area of use for AI in the energy industry. Among the 150 actors examined, AI methods for predictive maintenance are the third most commonly used or developed (by 26% of the organisations). By ensuring uninterrupted operation of

energy plants, AI methods – in predictive maintenance applications mostly based on machine learning – make a decisive contribution to the integration of renewable energies and increase business yields. According to provider data, in one application example, failures within production plants can be predicted as early as 60 days in advance and as a result savings of 12,500 EUR per wind turbine can be achieved (Boldare, 2019).

Example: Predictive maintenance from E.ON

E.ON is banking on artificial intelligence for maintenance activities and for improving energy efficiency. The energy provider has therefore developed a self-learning algorithm that can predict when the medium-voltage cable in its power grid will have to be replaced. For this purpose, the algorithm analyses external and internal data, such as the age and type of cables, maintenance and weather data (lightning, atmospheric conditions) as well as real-time information and can therefore prevent interruptions by implementing countermeasures early on. AI is also used to optimise the capacity utilisation of wind parks by analysing wind turbine data, which extends the service life of the individual turbines. According to studies conducted by the company itself, it was possible to reduce the incidence of grid failures by 30% using the intelligent approach compared with conventional methods (E.ON SE, 2019).

Challenges for the energy industry

As well as the numerous opportunities offered by AI for the energy sector, the risks also have to be considered. The automation brought by AI applications and the associated potential loss of jobs will not stop short of the energy industry. In Europe, as well as in China, the USA and Israel, AI is expected to have a more significant impact on jobs in production and in the construction sector. In the energy industry, this would affect manufacturing companies and makers of power plants, for example. But even in the case of service providers, processes will become automated.

Another challenge posed by the spread of AI applications and the associated computing power is the considerable increase in power consumption. According to estimates produced within the scope of the French AI strategy, energy consumption in the digital sector could increase ten-fold by 2030 and make up 20 to 50% of global power usage.

3.3 AI actors within the energy industry

According to data from McKinsey, more than half of all American companies are likely to have integrated AI into their corporate practice by 2030 (Bughin et al., 2018). A similarly high absorption rate in the energy sector could help actors within the energy industry to take advantage of the opportunities brought by this technology for themselves. In Israel, AI start-ups are being favoured by investors and the government when it comes to funding. A similar approach for encouraging AI start-up activity in the energy industry could also provide a clear signal that policymakers are committed to tackling climate change.

There are already some AI players that have devoted themselves to the energy sector. dena identified and analysed a total of 150 such players around the world in an investigation conducted throughout 2019. Based on this non-representative data, within the energy industry, start-ups and SMEs are the most actively engaged in the field of AI, accounting for 61%. This is hardly surprising, since disruptive technologies such as AI, for which the required skills are often lacking, pose entirely new challenges for companies with regard to their business strategy.

Start-ups, in particular, can innovate quicker than large corporations, as they acquire knowledge in a more targeted manner and via shorter routes, whereas large companies have to first “unlearn” established approaches in order to then be able to restructure their existing business model. Nevertheless, large corporations, which account for 19% of the organisations examined, usually have a significantly higher budget and can therefore purchase the knowledge from more innovative companies. Research institutes that devise AI approaches in the energy industry make up 20% of the actors investigated, with the need for basic research in Europe seemingly being greater than in the USA or Asia, for example. In the field of AI and energy, almost twice as many research institutions in Europe as in the USA are dealing with this topic. This is (not least) reflected in the European focus on basic research in contrast to the market- and application-oriented research in the USA.

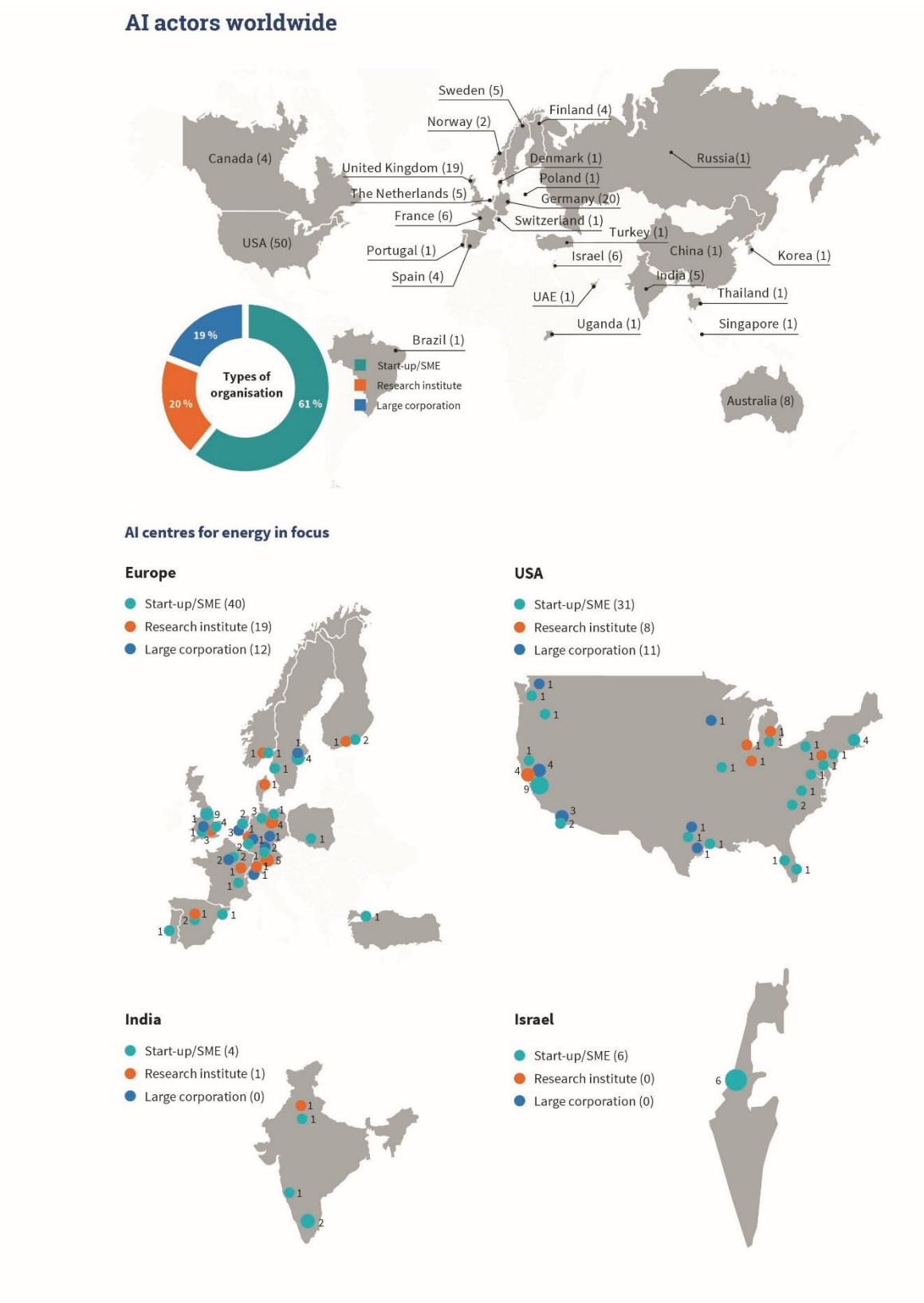

Figure 9: Global overview of a selection of AI actors in the energy industry (own graphic).

Globally, most of the organisations are located in Europe (70 actors) and the USA (50). In Europe, where predictions dominate compared to other parts of the world (26 compared to 11 in the USA), the United Kingdom and Germany (both with 19 players) can be considered the strongest drivers of AI in the energy sector based on this research work, followed by France (6), Sweden and the Netherlands (both 5).

In Asia, Israel and India appear to lead the way in the energy industry, with both more or less being on par with regard to the number of existing organisations according to the analysis (5 and 6, respectively). In Africa and South America, it has so far been difficult to identify organisations with an AI background. This finding is echoed by other analyses (Miller et al, 2019).

As already mentioned above, the biggest fields of application are operation optimisation, predictions, and predictive maintenance. The same ranking emerges from a more in-depth analysis according to type of organisation. Only large corporations seem to place greater emphasis on predictive maintenance than on predictions – approximately one third of all large corporations are pursuing the former, along with operation optimisation, whereas in only 6 out of 28 cases of this group are more geared towards predictions.

For the most part, many different types of AI are being used, but pure data analysis wins out in most cases (80%) – followed by image/pattern recognition (14%), which is used in particular when evaluating satellite images or drone shots. Drones, for example, are often used for wind turbines or offshore installations for error diagnosis and maintenance work. Robotics, speech/audio recognition and human-machine interactions are still rather rare in the energy industry.

Research at the nexus of AI and energy

The heightened vulnerability of the power grid due to the increasing contribution of renewable energies is driving calls for stability and reliability of supply. Across the world, universities, colleges and research laboratories are increasingly grappling with the question of where on the energy circuit to intervene so as to ensure maximum energy efficiency.
For example, the US Department of Energy's SLAC National Accelerator Laboratory at Stanford University in California is developing an autonomous, intelligent power grid as part of the 32 million USD pilot project Grid Resilience & Intelligence Platform (GRIP). It is hoped that machine learning methods and AI will provide for smooth integration of clean energy sources from solar cells and wind power without human intervention and comprehensively compensate for disruptive factors such as storms, solar obscuration and cyberattacks. The SLAC claims to be one of the first labs to research the use of AI for autonomously stabilising the power grid (SLAC National Accelerator Lab, 2017). The Norwegian Open AI Lab is also following a similar approach and is conducting research in three projects into the use of AI for predicting grid imbalances (IMPALA), for monitoring physical electricity markets (HAWK) and as an early warning mechanism when proactively detecting faults in the energy system (EarlyWarn) (Open AI Lab, 2018). And recently, a coalition of four technical universities in Denmark was announced, including Aarhus University. The coalition aims to jointly research into how the interplay between energy production and consumption can be improved using AI (Aarhus University, 2019). The scientists at the Solar Energy Institute of the Polytechnic University of Madrid are going one step further and are researching into how solar plants can best capture light spectra of the sun.

Using an AI cluster method, predictions about the various possible light conditions are created in order to improve the energy efficiency of photovoltaic plants (Universidad Politécnica de Madrid, 2018). In Asia, the Indian Thapar Institute of Engineering and Technology is investigating into automated inspection of solar cells for possible damage caused by temperature changes, pollution and UV radiation.

The researchers are hoping to achieve preventive and significantly faster inspection and maintenance of the panels, including off-site, with the help of cluster-based calculations such as machine learning and generalized fuzzy models. Moreover, they hope to be able to predict the output of the panels more accurately (India Today, 2019).

In future, it will be highly interesting to observe how start-ups hold their own against large corporations in the field of technology management, which control measures are put in place by politicians in consultation with scientists and what alliances will be formed in the changing AI innovation system. The measures available for a targeted application of AI in the energy sector will be set out in the following section.

4 Recommended courses of action for the integrated energy transition

The analysis has shown that the topic area of artificial intelligence is rapidly gaining prominence around the world and is slowly but surely making inroads into almost every aspect of our lives. Governments and scientists are strategically preparing for the use of AI and in the energy industry, too, there is growing potential for AI applications.

In the following, possible courses of action for policymakers, the energy industry and the AI scene in Germany will be proposed based on the findings of the global analysis.

Develop the technical infrastructure for AI applications – and in so doing encourage energy efficiency

State of affairs:

A key success factor for the widespread use of artificial intelligence in the energy industry and in all other sectors is the availability of computing power. As such, over the coming years, massive investments are required for developing the technical infrastructure of state and private-sector actors. This is critical for being able to compete on the world AI stage. However, the predicted increase in global computing capacity for AI applications will also bring with it a significant rise in energy consumption. This stands at odds with the goal of using digital technologies for protecting the climate and reducing emissions.
Even if predictions relating to the amount of data generated and the use of AI are only partially correct, digitally-assisted processes will use up 25 TWh of power in 2025 in Germany alone (Burkert, 2017). And although some international corporations are already announcing that they are obtaining all the energy they require for their computing centres from renewable sources, the energy efficiency of IT technology will play an important role.

According to a price analysis published in January 2020 by the digital association BITKOM, it was up to six times more expensive to operate computing centres in Germany in 2019 than in other European countries, such as the Netherlands, on account of the high ancillary electricity costs. There is therefore the risk of experts moving abroad. In order to preserve the attractiveness of Germany as a business location for Internet companies, BITKOM is calling for political incentives for energy efficiency and electricity pricing based on CO_2 emissions (Mewes, 2020).

Measure:

In order to provide a solid basis for analysing the expected challenges in relation to increasing energy consumption due to digitalisation and in particular AI, a study project should be set up to examine future energy requirements. It will also be important to consider the temporal and spatial pattern of energy use on the one hand (where is the data centre located and when does it consume energy?), to assess the benefit (which computing processes is the AI and thus the energy being used for?) and to consider the type of energy being used (is the AI being operated using CO_2-free energy sources?) on the other hand. When conceiving and implementing the project, actors from the political sphere and from the energy and digital industries should be included.

In addition to existing research projects, policymakers should also encourage the development of energy-efficient IT technology with other funding programmes for science and industry. This measure could become a real European flagship through the development of standards for labelling "green energy use for digital processes" within the scope of the study project. The results could constantly be communicated to the business world by way of an information campaign.

Data models for the energy industry – focus on the origin and use of data for economic as well as ecological model development

State of affairs:

Data is vital for training various forms of AI. At the same time, it is essential to ensure the protection of digital information and datasets, especially if the AI algorithm and the associated processes and results cannot be fully traced. The plausibility of the data origin must be a clear objective of governments and industry, especially since it can be assumed that the efficacy of AI is closely correlated with the quality of data and the use of this digital technology will play an important role in the economy in the future.

Measure:

Experts from various disciplines should be brought together with the aim of developing initial models that deal with how data origin and use can be technologically traced and economically exploited. If business in the energy sector also shifts increasingly towards a data-driven business world in the future, then the energy sector must also keep an eye on the developments in this area from an early stage.

Promote pilot projects for testing synergies with blockchain technology

State of affairs:

As the analysis clearly shows, some countries are already very actively forming research clusters and labs that focus specifically on artificial intelligence for energy and environmental protection applications. This is a significant step in the right direction, since the first links between the topics of AI, energy transition and environmental protection are being forged and the huge potential of AI for corresponding measures is being recognised. Aside from the essential contribution of research in this field, it is also important to go one step further and try out specific applications under real-life conditions. The challenge consists in not viewing AI separately, but rather in combination with other innovative technologies such as blockchain and investigating and testing which potential synergies between blockchain technology as infrastructural base and artificial intelligence as enabler of numerous applications and business models could be the driving force behind the digital energy system of the future.

Measure:

In order to meet this challenge, policymakers should continue to support cross-technology pilot laboratories. Existing or planned measures serve as good starting points for this. In a similar way to the United Arab Emirates, which have rooted their AI Lab for Renewable Energies in the national AI strategy, the German government – in its blockchain strategy – announced a pilot laboratory for carrying out pilot projects that test possible use cases of blockchain technology for the energy industry.
This objective gave rise to the initiative of the Future Energy Lab, which is to be founded in the spring/summer of 2020. The pilot laboratory, whose initial focus is to test blockchain technology, shall explore a variety of technologies in the short- to medium-term.

In this context, policymakers should provide more support for AI pilot projects in the Future Energy Lab or encourage dovetailing with existing blockchain pilot projects. A first pilot project could deal with the energy consumption of AI, for example. Other future project ideas could proceed from the fields of operation optimisation, predictions and predictive maintenance, in which AI is most frequently applied in the energy industry today.

Inform AI start-ups of the potential and challenges of the energy sector

State of affairs:

As the international actor analysis shows, a large portion of actors in the field of AI come from start-ups that are harnessing this highly dynamic technology and driving forward practical applications of artificial intelligence for the energy transition with their innovative business models. A major advantage is also that AI algorithms are often generic tools that can be used in a variety of different sectors. Therefore, it would be useful for many AI start-ups to check whether they can transpose their business models onto the energy sector. However, due to its critical infrastructures, the energy sector is one of the more tightly regulated sectors, which poses challenges for many start-ups and their business models. As shown by the Start Up Energy Transition Laboratory (SET Lab for short – running period 01–12/2018) set up by dena, within the scope of which various communication platforms (round tables and innovation workshops with roughly 50 German start-ups from the energy sector) were offered for promoting innovative business models, start-ups are in great need of advice so that they can identify challenges early on and factor them into AI business models focused on the energy industry.

Measure:

In order to address AI start-ups' great need for energy industry-related advice and to achieve the most positive effect possible on the integrated energy transition, funding needs to be provided for consultation programmes for AI start-ups. Within the scope of these consultation programmes, the basics of the energy industry and the specific regulatory circumstances thereof need to be explained and there must be direct and intensive consultation on the specific business models. To this end, the first step should be to search for existing support and consultation programmes for AI outside the energy sector as well. A separate module that can be incorporated into existing formats should then be set up with the aim of informing the start-ups reached via the consultation programme of the various application options within the energy industry. An example of this could be the development of energy-oriented modules for digital clusters such as blockchain, open data or AI. For AI start-ups with "industry-agnostic" business models, these channels could be used to provide a consultation programme that prepares them for the energy industry as a future target market and informs them of which regulatory challenges they have to take into consideration in order to make their business model a success in the energy market. In this way, young and innovative companies will be motivated to contribute to the integrated energy transition.

Set up a dialogue forum "AI and data for the energy transition"

State of affairs:

The analysis clearly shows that the topic of AI in no way slots neatly into the energy industry, but rather is much more closely matched to other technologies and fields of application. Although the potential of AI and the interest in it is great, there is also a great deal of uncertainty regarding the technological and regulatory questions – above all in relation to data management and the data economy, which are crucial for the onward development of AI in general.

Many aspects, such as the provision of data, still need to be clarified and/or discussed in-depth among the relevant stakeholders. This requires further investigation of the different perspectives and occasionally contrary needs of the various actors, such as start-ups, which rely on data provision for their business models, citizens, whose main concern is that of the conflict between customer benefit, data protection and data security, and public institutions and firms, who have doubts about giving away their valuable data.

Measure:

In order to promote an open, cross-sector dialogue and extend the reach of the discussion, there should be a dialogue forum in Berlin and other German cities twice a year. This should invite the population to hold discussions with experts from the relevant fields and to learn more about the topic of the “AI-assisted energy transition”. By conducting a public discussion on current developments in AI in relation to the energy transition and in this way increasing acceptance of the technology, the topic of AI can gain enough traction to get the population involved in a technical-political debate. To this end, known formats such as panel discussions can be combined with innovative channels such as podcasts in order to ensure that citizens are continuously kept in the loop about the results. In conjunction with this dialogue forum, surveys and market tests on issues relating to AI in the context of the energy transition, in particular with regard to data use and data management, could be conducted and the results could then serve as a basis for further developments in this technology for the energy industry. The participating public could effectively serve as a peer group.

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Abbreviations

AGI	Artificial General Intelligence
AI	Artificial Intelligence
AIE	Artificial Intelligence Exploration
AI2	Allen Institute for AI
ANITI	Artificial and Natural Intelligence Toulouse Institute
ANR	Agence nationale de la recherche
BAT	Baidu, Alibaba and Tencent
BEIS	Department for Business, Energy and Industrial Strategy
BMBF	Federal Ministry of Education and Research
CFI	Leverhulme Centre for the Future of Intelligence
CLAIRE	Confederation of Laboratories for Artificial Intelligence Research in Europe
DARPA	Defense Advanced Research Projects Agency
DCMS	Department for Digital, Culture, Media & Sport
DEBEIS	Her Majesty's Principal Secretary of State for Business, Energy and Industrial Strategy
DFKI	German Research Centre for Artificial Intelligence
EC	European Commission
ELLIS	European Laboratory for Learning and Intelligent Systems
EurAI	European Association for Artificial Intelligence
FLI	Future of Life Institute
R&D	Research and development:
GAFA	Google, Apple, Facebook and Amazon
GCI	Global Connectivity Index
GPUs	Graphic Processing Units
GRIP	Grid Resilience & Intelligence Platform
HPC	High Powered Computer Systems
IAIS	Fraunhofer Institute for Intelligent Analysis and Information Systems
IDRC	International Development Research Centre
IIA	Israel Innovation Authority
ICT	Information and communications technology

INRIA	Institut national de recherche en informatique et en automatique
IoT	Internet of Things
IRENA	International Renewable Energy Agency
KUST	Khalifa University of Science and Technology
MESRI	Ministry of Higher Education, Research and Innovation
MIIT	Ministry of Industry and Information Technology
MIRI	Machine Intelligence Research Institute
MSRM	Munich School of Robotics and Machine Intelligence
NAII	Nordic Artificial Intelligence Institute
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
NSTC	National Science and Technology Council
PRAIRIE	PaRis Artificial Intelligence Research InstitutE
SAIL	Stanford Artificial Intelligence Laboratory
SDGs	Sustainable Development Goals
SMEs	Small and medium-sized enterprises
WIPO	World Intellectual Property Organization

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