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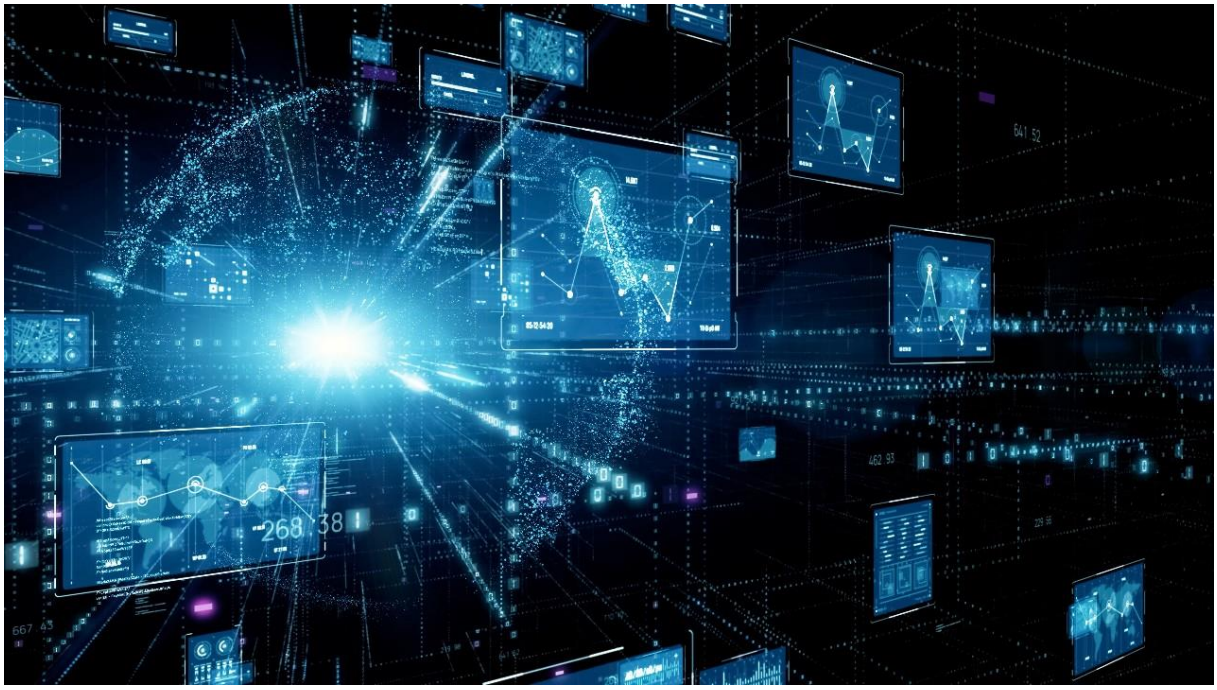

Artificial Intelligence in Innovation Processes

A study using the example of an innovation research institute

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Artificial intelligence in innovation processes

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Notes

Table of contents

1 Introduction

At a time when the development of new products has become more complex because many ideas have already been implemented, technologies have already been developed and solutions have already been brought to market, innovation processes can benefit more than ever from being supported by artificial intelligence (AI). AI can speed up innovation processes that previously would have tied up a lot of people. Companies are increasingly using AI in their innovation processes, whether to collect large amounts of data in the idea phase (ideation), to accelerate development and testing processes, or to address target groups in a targeted manner (market launch).

In the course of this AI project, interviews were conducted with members of the research institute's departments. The focus was on what role AI can play in (company and inter-company) innovation processes from the perspective of selected employees. The objectives were to gain a better understanding of...

- which departments at the research institute deal with AI in innovation processes and how,
- how the interviewees assess the general and specific effects of AI in the innovation process,
- what challenges are seen in the implementation of AI in innovation processes and
- how the potential of AI can be better exploited.

This project also serves to stimulate AI-related interdepartmental exchange and to provide an overview of who is working in innovation processes in the context of AI. Ultimately, this project should also help to make statements about where the research institute stands in relation to AI and to what extent AI projects could be accompanied in the future, for example at company and political level.

The report is structured as follows: A brief literature review on AI in innovation processes with an analysis of selected articles (Table 1) is followed by an outline of the approach. The main chapter presents the results, which are roughly structured according to the interview questions. Part of the results is a summary of the impact of AI on the innovation process, compiled from the interviews and the literature review (Figure 4).

2 Brief Literature Review on AI in Innovation Processes

It is worth taking a brief look at the upheavals that the digitalisation of innovation is bringing about before this section looks at the literature that deals with AI and innovation. Without specifically addressing AI, Nambisan et al. (2017, p. 224f.) have argued in their article that the digitisation of innovation is increasingly challenging three established assumptions:

1. Innovation as a bounded phenomenon: Innovation is "no longer a well-bounded phenomenon, but is characterised by unpredictability, dynamism and fluidity".
2. "Enacted" innovation: The locus of innovation activity is shifting "away from static centralisation to a widely distributed, less predefined state involving multiple collaborative actors."
3. Innovation processes and outcomes are separated: "Innovation processes and outcomes [are] no longer seen as isolated entities, but as dynamic and complex interdependencies".

AI can be defined as "the ability of a system to correctly interpret external data, learn from that data, and use those insights to achieve specific goals and tasks through flexible adaptation" (Kaplan and Haenlein 2019, p. 15). AI can be defined as information technology (IT) methods "that enable machines to perform human-like cognitive functions" (Rammer et al. 2022, p. 1).

Many companies have started to integrate AI into their innovation processes. Hutchinson (2021, p. 628) speaks of AI as a technology that has the "potential to become both a *general-purpose technology* and a method of invention". This potential distinguishes AI from other digital technologies. According to Hutchinson (2020, p. 4), this technology will have a disruptive impact a on all industries. The IT industry association Bitkom (2022) revealed in a recent study that only 9% of the 606 companies surveyed (all industries, 20 employees or more) use AI - compared to 8% in 2021 (Bitkom 2021). The tenor of the study is that although companies recognise the importance of AI, the actual use and application is only progressing slowly[1] .

Research by Rammer et al. (2022, p. 1) indicated that companies using AI achieve "significantly higher innovation outcomes". According to the authors, AI technologies used in process innovations contributed to "6% of the total annual cost savings in the German economy". Rammer et al. (2022, p. 2) found that the "use of AI is associated with annual sales of world firsts in these companies of around €16 billion". According to the authors, this is related, among other things, to the fact that AI changes the R&D process of companies by analysing large data sets and leads to cost savings, especially in process innovations. The study by Füller et al. (2022, p. 17) showed that innovation managers believe that "AI can improve the overall outcome of innovations by more than 50% compared to existing innovation approaches".

Leitl, Brandolisio and Golta (2021, n.d.) identified six areas of application in which artificial intelligence can be helpful in innovation projects. They also call these six areas of the innovation process "innovation accelerators":

[1] A study by the German Confederation of Skilled Crafts (ZDH) and Bitkom can be mentioned in this context. According to the survey of 503 craft enterprises, AI plays a role in only 1% of the respondents.

- Recognising trends: The US Securities and Exchange Commission (SEC) is mentioned as an example, whose computer systems analyse texts, images and videos for trends and summarise them in a tailor-made way.
- Gain insights into user behaviour: For example, airports use AI models to filter out causes for delays.
- Create personas: Providers evaluate 20 different data sources to visually represent a typical customer group.
- Sifting through ideas: For example, the AI helps the logistics company DHL to filter out the best of 60,000 suggestions each year.
- Develop designs: AI learns based on previous designs. As an example, the designer Philippe Starck's chairs designed with the help of AI models.
- Prototype testing: For example, the AI can simulate how a certain food is perceived by certain target groups based on many documented taste tests.

The following table lists selected research articles that have dealt with AI in the innovation process from different perspectives. The table shows the respective research questions, selected definition and key statements as well as the role of AI within the innovation process mentioned in the article. See chapter 3.2 for information on how these articles were selected from an extensive list for more detailed analysis.

Author (Year)	**Magazine**	**Research question / objective**	**Definitions**	**Selected key statements**	**The role of AI in the innovation process**
Filler et al. (2022)	Technological Forecasting & Social Change	How do managers perceive the potential of AI for **innovation management** and what impact do they expect it to have on the design of their innovation processes (p. 1)?	The **innovation process** describes the sequence of different activities that are carried out to seize an opportunity and bring an idea to market	(1) AI has the potential to transform the practice of innovation management by enabling a much more effective and efficient innovation process, ushering in a new era of innovation (p., 1) (2) AI-enabled innovation management requires significant technical and organisational change to address the challenges it poses (3) AI-based innovation management cannot be implemented with a one-size-fits-all approach (p. 2)	(1) **Identifying opportunities** and generating ideas: AI can identify problems, opportunities and threats and thus generate ideas faster (2) AI supports **idea evaluation and selection** (3) AI contributes to **concept and solution development by** shortening experimentation cycles (4) **Commercialisation phase**: AI helps to address customers in a more targeted way

Hutchinson (2021)	IEEE Transactions on Engineering Management	How can AI be used with a specific goal, namely innovation in organisations (p. 629)?	**Self-innovating artificial intelligence** (SAI) refers to the organisational use of AI with the aim of gradually enhancing existing products or developing new ones based on insights derived from the continuous combination and analysis of diverse data sources (p.1)	With SAI, companies could change their entire innovation strategy as they struggle to learn ambidexterously (both incremental and exploratory innovation) (p. 636)	- SAI can reduce **experimentation and product development costs** (p. 637) Beyond the innovation process: AI is expected to transform entire markets and industries -->which could ultimately lead to a fourth industrial revolution (p. 636)
Kaplan & Haenlein (2019)	Business Horizons	How does AI differ from related concepts such as the Internet of Things and Big Data? (S. 15)	**Artificial intelligence** (AI) defines the ability of a system to correctly interpret external data, learn from such data and apply these insights to achieve specific goals and tasks through flexible adaptation (p. 15)	- Machines must be controlled to avoid autonomous decisions and implicit bias - Lifelong learning among employees is becoming important to make the best use of AI	Indirectly, e.g. (p. 22): - Customers and stakeholders need to build trust in the capabilities and recommendations of AI to make insights gained actually usable and legitimate
Marshall et al. (2021)	Strategy & Leadership	How can digital technologies be used to create new opportunities in the field of open innovation?	**Cloud**: The emergence of the cloud - and especially the hybrid cloud - is helping to address the challenge of integration and collaboration. It enables companies to connect, greatly improving the processes of integrating, moving, sharing and accessing data (p. 33)	The application of exponential technologies such as AI accelerates and improves innovation dynamics and provides more meaningful insights for the development of new solutions and approaches (p. 36)	- AI permeates the innovation ecosystem, accelerating the discovery process by complementing and extending the capabilities of all ecosystem participants (p. 33) - AI accelerates the process from traditional to **open innovation processes**
Kakatkar et al. (2020)	Business Horizons	How can AI be used in the innovation process within the framework	**AI is** about endowing machines with a kind of intelligence that is	AI can play a key role in the innovation process by driving several aspects of innovation analysis (p. 172)	AI can arguably play the role of creative enabler and partner to the innovation manager in the data-

		of innovation analytics? (S. 171)	mainly attributed to humans.		driven innovation process
Verganti et al. (2020)	Journal of Product Innovation Management	To what extent does AI lead to a new understanding of how design thinking can drive innovation processes in organisations?	**Design thinking**: human-centred innovation driven by design, inspired by the needs of users	Creative problem-solving is done to a significant extent by algorithms, so human design is increasingly becoming an activity of sense-making, i.e. understanding what problems should or could be addressed (p. 212)	In AI-enabled companies, the role of humans is not to develop complete solutions (which are further developed by AI in real time), but to understand which **innovation problems** are of importance and to frame the innovation efforts (p. 226)
Rammer et al. (2022)	Research Policy	While expectations of AI's potential for disruptive innovation are high, there is little data on the extent to which AI is currently transforming innovation in companies.	**AI** generally describes information technology (IT) methods that enable machines to perform human-like cognitive functions (p. 1)	This is a rather small group of companies that are able to derive significant benefits from AI The figures for the economy as a whole show that investing in AI pays off (p. 13) Results show that AI in industrial innovation can boost the introduction and sale of novel products and thus increase the competitiveness of companies	AI is transforming the R&D process through the extensive use of large data sets and improved predictive algorithms (p. 2) AI leads to cost savings, especially in process innovations (p. 13)
Petrescu et al. (2022)	Industrial Marketing Management	What contribution can AI make in B2B innovation management?	**Artificial intelligence refers to** the theory and development of machine intelligence that mimics aspects of human intelligence (p. 62)	AI influences human and business activities and affects the way companies make strategic decisions by incorporating neural networks and machine learning in decision-making processes (p. 61)	AI can help B2B companies (1) match customer needs with digital offerings, (2) move from descriptive to prescriptive analytics, and (3) combine storage, analytics and data ecosystems to develop data-driven solutions (p. 68) --> AI can foster co-creation in the AI innovation process

Table 1: Research articles on the role of AI in the innovation process

3 Methodological Approach

The data for this AI project was obtained through interviews, a literature review and a keyword analysis. The 10 interviews with 13 members of the institute's departments provided the primary data presented in Chapter 4, "Results". These departments cover subject areas such as energy policy, knowledge economy, foresight and policy and society. The primary data obtained was expanded and supplemented with data from the literature analysis. Some of the articles analysed can be found in Table 1 of Chapter 2.

In the following, we will take a closer look at the keyword analysis conducted and shed light on the origin of the publications and patents that came up in the course of the keyword search on the topic of AI in the innovation sector. It then explains how the literature analysis was conducted. The chapter ends with an overview of the semi-structured interviews conducted and the rationale for choosing this methodology.

3.1 Keyword analysis: Industries and patents

This chapter examines the prevalence of the use of AI in innovation-related activities in Germany's highest-turnover industries. The industries are selected on the basis of the turnover of companies in the manufacturing sector according to the Federal Statistical Office. For the study, the titles and abstracts or summaries of the English-language publications and patents published from 2000 to 2021 (cut-off date: 13.01.2022, tool: Dimensions) with reference to these industries and to the topic of AI in the innovation sector were examined using a keyword analysis. The analysis identified a total of just under 7,000 publications, most of which come from the USA, followed by China and the United Kingdom. Germany is in 4th place.

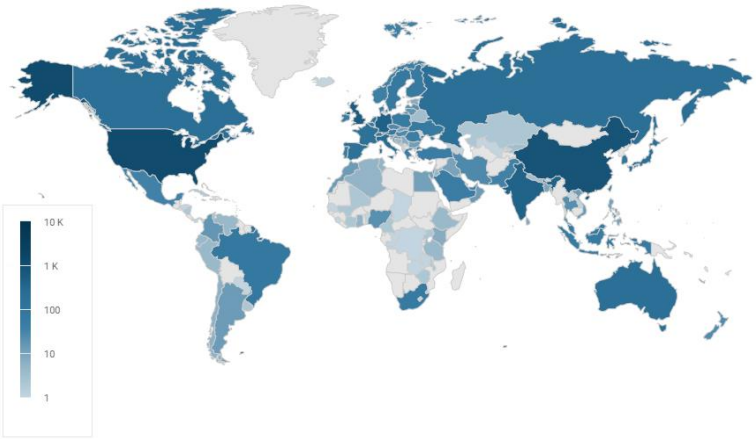

Figure 1: Origin of publications

In addition, over 200 patents were identified that originated primarily in China, followed by India and the USA. Germany shares 10th place with several other nations.

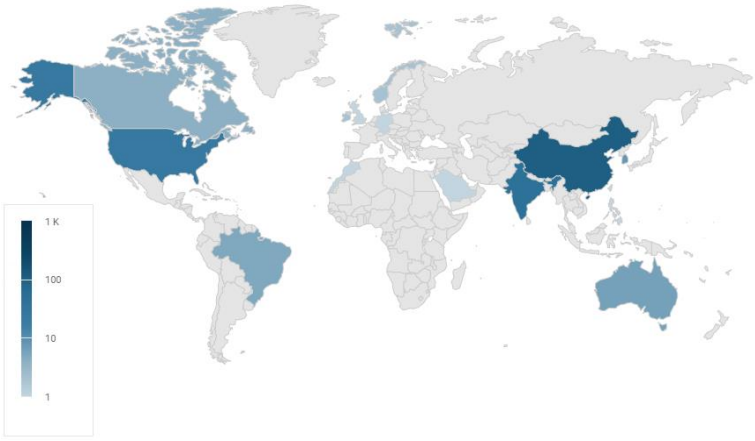

Figure 2: Origin of the patents

With regard to the evaluation, the higher the number of these publications or patents containing the corresponding keywords in an industry, the more extensively research and the use of AI in innovation activities is discussed and potentially adopted in this industry. A high number of citations indicates a high importance of the information.

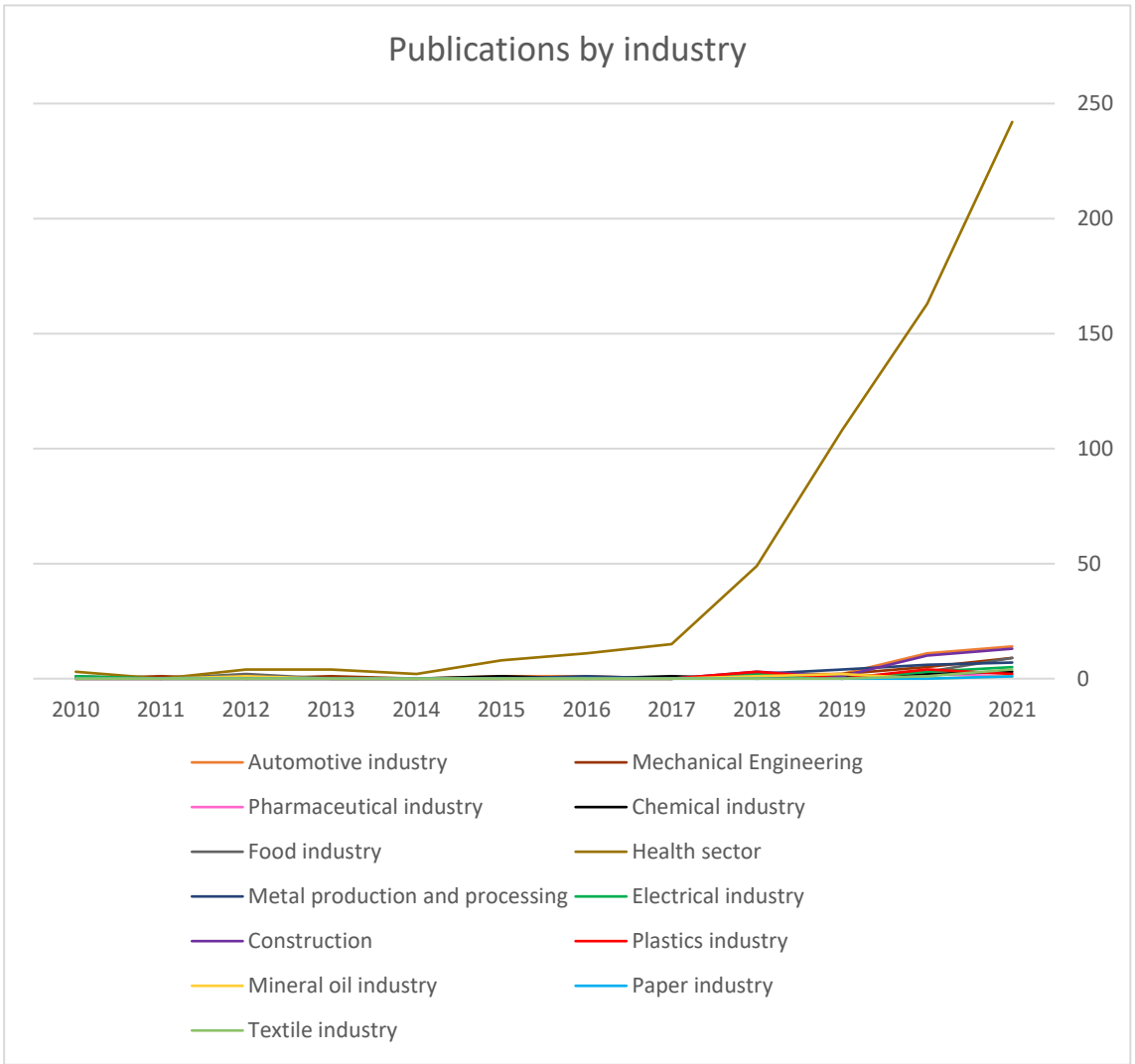

Figure 3: Publications by industry

When reviewing the analysis results for the publications, it becomes clear that the number is increasing significantly overall from 2018 and almost across all sectors. By far the most publications are in the healthcare industry, followed by the automotive industry and the construction industry. While the USA leads in the number of publications in the healthcare sector, Germany is ahead in the automotive and construction industries. However, the most important sector-specific publications come from the USA, China and the United Kingdom in terms of citations.

	Health sector	**Automotive industry**	**Construction**
1st place	USA	Germany	Germany
2nd place	United Kingdom	Russia	China
3rd place	India	USA	United Kingdom

Table 2: Ranking of publications by industry and country

3.2 Keyword and literature analysis

The nearly 7,000 publications mentioned in 3.1 resulted from a search focusing on the use of AI for innovative activities. A subsequent search using the Dimensions.ai database, which specifically looked for the keywords "AI" or "artificial intelligence" and "innovation process" or "AI" or "artificial intelligence" and "innovation process" in the title and abstract of the publications, came up with a list of 94 articles (note: this Excel list is available on request). After subtracting duplicate and non-English and German language articles, the research articles were reduced to 88. The abstracts of these articles were scanned and included in the literature review. Selected articles were listed in Table 1 and analysed in more detail.

In addition, there were articles that had reference to AI in innovation processes, but the keywords mentioned did not appear in the title or summary. Among the seven articles analysed in Table 1, Füller et al. (2022) and Rammer et al. (2022) are two articles that did not appear in the extensive list.

3.3 Semi-structured interviews

10 semi-structured interviews were conducted with 13 members of six different departments of the research institute (see Table 1). On the one hand, the interviewees were selected on the recommendation of the head of the institute's AI group. On the other hand, people were contacted who had contact with AI in their department or who had an overview of who was working on related projects in the department. Table 3 shows the dates on which the interviews were conducted and the number of interviewees per department.

In order to understand the basic understanding of AI and digitalisation, respondents were first asked to define the difference between AI and digitalisation. This was followed by questions about

the concrete activities of the departments in relation to AI, what impact AI can have on the innovation process in general, as well as phase and area specific. It was also asked what an innovation process could look like that would better exploit the potential of AI, and what the challenges might be in implementing AI. An additional question asked at the end of the interviews was how AI and sustainability fit together.

Departments	Date	Number of interviewees
D-I	2.3.; 4.3.2022	2
D-II	4.3.; 8.3.; 9.3.2022	3
D-III	20.4.2022	1
D-IV	3.3.; 9.3.2022	4
D-V	3.3.2022	1
D-VI	14.3.2022	2

Table 3: Number of interviewees per department and date of interviews

Semi-structured interviews were chosen to give interviewees more freedom to talk about issues they are familiar with or know more about, without being tied to a fixed protocol (Kvale and Brinkmann 2009). This allows both the interviewer and the interviewee more flexibility in discussing and elaborating on certain topics. Thus, more can be learned about the interviewee's attitudes, issues and position within the organisation (Blumberg, Cooper and Schindler 2014).

4 Results

In the following, the results from the semi-structured interviews are presented along the individual questions.

4.1 Associations around the topic of AI

First, the interviewees were asked which thoughts and topics first come to mind when they hear "artificial intelligence (AI)". Three large answer groups could be identified, each with about 10 mentions. The most frequently mentioned was the technical implementation through algorithms, neural networks and for process optimisation and increased efficiency and the associated challenges such as complexity and large amounts of data. AI was also cited as an "opportunity to make systems more efficient" (#8, D-II).

Just as often, the answers concerned the intelligence and automation of AI with terms such as "(partially) (self)learning systems", "machine learning" and "deep learning". Thus, the interviewees drew a distinction between strong and weak AI. For example, one interviewee said that "AI is ultimately only as smart as it is programmed to be" (#11, D-VI).

The third large response group includes a critical examination of the topic of AI in terms of potential and risks. While potential is seen in the empowerment of sustainable transformation, the risks mentioned are outweighed by AI. Misconceptions, possible discrimination and impenetrable "black box" behaviour of AI were addressed. Likewise, great and "disappointed expectations" (#4, D-IV), especially due to the lack of *use cases, were presented, the* high energy consumption of AI was addressed and the topic was said to have a lot of "ideology ballast", which is why AI was sometimes assessed as a vision of the future. In the following comment, the concern that this vision of the future can bring certain side effects resonated:

Up to what point can we control the AI in such a way that we do not make ourselves superfluous?

(#8, D-II).

In one interview, the "robotics sector" (#10, D-IV) was still associated with the topic of AI. The topic of robotics was still raised in the context of human-machine interaction (#1, D-IV) and was cited elsewhere as an example of which possibly dystopian scenarios ultimately did not come to pass (#13, D-III).

4.2 Distinction between digitalisation and artificial intelligence

The second block of topics includes distinctions made by the respondents between digitalisation and artificial intelligence. For some, digitalisation includes everything that was manual and is digitalised (e.g. documents) or networked (e.g. communication) (e.g. #6, D-I; #7, D-II). One interviewee summed up the difference as follows:

The main difference between digitalisation and AI is machine learning. If a system does not learn, then it is merely a digital solution (#6, D-I).

According to one interviewee, "digitisation creates the precondition for AI" (#9, D-IV), while in other conversations AI was again called an "*enabler*" *(*#11, D-VI) or "*accelerator*" *(*#8, D-II) for the

spread of digitisation. This goes hand in hand with Kakatkar et al.'s (2020, p. 171) finding that AI can play the role of a "creative enabler and partner to the innovation manager in the data-driven innovation process". For some of the respondents, AI represents a new part or facet of digitalisation that is much "broader" (#9, D-IV; #13, D-III) than AI. This is exemplified by the statement of one interviewee that "AI is part of the overriding trend of digitalisation" (#1, D-I).

For other interviewees, AI lies across digitalisation or has links to it. Still others make it dependent on the context whether it is AI or just digitisation, as the following questions show: "Is AI something you put on top of digitisation [...] to push it a bit further? Or is AI something new [...] which goes far beyond that, [than what] we have seen in digitalisation?" (#3, D-IV). In the same conversation, the interviewee presented two currents that he picks up on when talking about AI: On the one hand, there are the people who ask the same questions about AI as they do about digitalisation:

Where are the use cases? How can this be used efficiently? What do the companies get out of it? How can they be made aware of the topic? Is it only the big companies that use it [AI]? Who has the expertise? How does this get into the companies?

On the other hand, there would be the people who talk about AI as "a whole new system and AI as a game changer" (#3, D-IV).

For one interviewee (#1, D-I), AI, in contrast to digitalisation, is "not rule-based but learning-based" and possibly even autonomous. It does not use rigid programming code, is partly intransparent and is not a stochastic application in which the relationship between cause and effect is clear. Nevertheless, for some respondents, digitisation and AI are buzzwords that are sometimes used synonymously in colloquial language or in marketing. Roth and Oks (2020, p. 158) pick up on the parallels in the development of AI and the development of digitalisation that can be heard in this section and state that only the "breadth of application fields [...], the spread of smart devices and other digital infrastructures and the increasing acceptance on the part of users" led to radical innovations.

4.3 General impact of AI on the innovation process

In this subsection, the focus is on responses about the general impact of AI on the innovation process, before the next section looks at specific impacts and sector-specific examples. The general impact of AI on the innovation process was seen by some respondents across all steps of the process. For example, one interviewee explained:

AI spans all phases: from the identification of market and improvement potential in products through the analysis of customer usage and machine data [...] to the development phase, e.g. the acceleration and improvement of technical developments, but also the development of services, through to the market launch phase (addressing the customer, sales channels, etc.) (#1, D-I).

In this context, it was also mentioned in some interviews that AI accelerates innovation processes (e.g. #8; D-II) and will have even greater benefits "along the value chain" in the future - both for small and medium-sized enterprises (SMEs) and large companies. From the authors' interviews with SMEs, this potential can be confirmed, although the benefit depends strongly on the networking of the company and the demonstrated depth of value creation. One interviewee spoke of the fact that thanks to AI and "high performance computing, evaluations of large amounts of

data [can be made] to arrive at meaningful insights" (#9, D-IV). Furthermore, AI can help accelerate the early stages of the innovation process in particular, thereby improving the efficiency of the innovation process. In this way, AI could make an innovation process possible in the first place because certain activities were previously too time-consuming for a human, for example.

In some interviews (e.g. #7, D-II), it became apparent that some departments can say little about corporate innovation processes, as the focus is rather on "contract research for ministries" (#11, D-VI). However, there is a great need there, which is shown, among other things, in the project of the Federal Ministry of Economics and Climate Protection (BMWK), "Roadmap Energy Efficiency 2027".

Specifically in the idea phase, quite a few of the respondents (e.g. #8, D-IV; #9, D-II) see great added value in the use of AI. According to them, it can primarily contribute to identifying new market potentials or product improvement potentials (e.g. for recalibrating machines) by analysing customer usage behaviour, e.g. in social media or machine data. These ideas can be fleshed out to the concept level with the help of AI. It was also stated that AI can provide new types of data that are the starting point for generating ideas for innovations. AI serves as a tool for knowledge provision. An example of this is data that is later used for predictive maintenance applications. In SMEs, however, the use of AI in the idea phase is rather rare.

In the development phase, the respondents see an acceleration or improvement of the process and the possibility for new business models, for example through the sale of data, which are particularly interesting for start-ups.

Individual respondents also see an acceleration and associated cost reduction in the testing phase, specifically in measuring the effectiveness and probability of success of product candidates and alternatives.

In the market launch phase, AI is expected to improve the way customers are approached for marketing, especially on digital sales channels.

Basically, the benefit of AI in the innovation process depends on the level and perspective of observation. Companies sometimes assess the benefits of AI differently than research institutions that focus more on the innovation system. Similarly, the expected benefits of AI can differ between developers and users of AI.

4.4 Concrete impact of AI on the innovation process in the field of activity

In addition to the general effects of AI on the innovation process, we wanted to know from the respondents what concrete effects AI has on the innovation process in the area of activity of the research institute's departments. The results were differentiated by industry.

In the **pharmaceutical industry**, "great potentials" (#10, D-IV) are seen, as the use of AI is suitable for both creativity and efficiency in its innovation processes. For the identification of new applications for certain active substances, many tests can be carried out on different, data-based models instead of animal experiments or even clinical studies with human subjects, which are associated with great limitations. This could speed up the process of drug candidate evaluation and lead to new results that were not possible in the past due to complexity. This is also accompanied by a democratisation in the market, which also enables smaller companies to enter the market and can thus lead to a further acceleration and cost reduction. In the area of healthcare,

the interviews made it clear that AI plays a role especially when innovations are already on the market. For example, AI enables entirely new business models such as "wellness apps" (#9, D-IV).

In **industry, the** generation of ideas could be mapped much more efficiently by using AI algorithms on customer and machine data. For example, it could be used to recommend similar or complementary products or to improve analysed user behaviour. However, it remains to identify new fields of application and potential for improvement. For radically new industrial processes that would amount to a game changer, strong AI would be required, but this is still far in the future.

In the **service sector**, the use of AI in the innovation process is not as systematised as with products. The focus here is less on technical development and more on analysing consumer behaviour, which is important for offering complementary goods via digital sales channels.

In the **energy industry,** the use of AI is very application-oriented. The focus is, for example, on the development of smart systems for the integration of renewable energies into the power grid and the control of "decentralised energy systems" (#11, D-VI), especially by controlling the demand for electricity. Data at the household level is currently not available to a sufficient extent to make it usable for start-ups for innovations.

In the area of **smart cities,** the use of AI is similarly application-oriented. In water management, for example, it refers to "flood and heavy rain prevention" (#7, D-II), wastewater disposal or the measurement of soil moisture.

In the **mobility sector, the** collection of vehicle data with the help of AI can trigger innovation processes. For example, they can point out neuralgic points in the product that would otherwise not be suspected and thus trigger product improvement. By tapping information "over the air" (#8, D-II), the target groups for innovations can also be concretised. The use of AI also lends itself to accelerating processes while maintaining quality in the test phase up to the finished product.

In **science,** the use of AI can help to identify potential new research topics using "bibliometric data" (#6, D-I) or to identify relevant literature more quickly through intelligent publication suggestions. In addition, AI can provide input for innovation processes, for example in the creation of feasibility and market studies, requirements analyses and roadmaps, and provide helpful tools.

In contrast to the innovation processes considered so far, some business areas are also active at a higher level: the **innovation system** and the transformation of economies. Here, changes in industries, for example in terms of business models and practices, play a role.

The general and concrete effects of AI on the innovation process supplemented by a literature review are shown in Figure 4. The individual steps of an innovation process vary depending on the company and the scientific approach. The innovation process shown in Figure 4 consists of the idea phase, test phase, development phase and market launch. See Appendix 1.2 for a more readable representation of this figure.

Effects of AI in the innovation process		Idea phase	Development phase	Test phase	Market launch
	General	economic transformation process/innovation system instead of innovation process: Business models, practices and industries are changing			
		Identification of new market potential or potential for improvement in products by analysing customer usage and machine data Provision of new types of data as a starting point for innovations Generation of new ideas through to the finished product	Acceleration and improvement of the development process Selling data as a new business model	Acceleration/cost reduction of the measurement of the effectiveness/probability of success of product alternatives	Better approach to customers for marketing through new sales channels
	Pharma-ceuticals	New applications as no test on living organisms required (D-IV)	AI enables more efficient use of data and speeds up processes The Swiss cosmetics manufacturer Givaudan developed a product development platform for cosmetics with AI and suggests the ideal composition of new cosmetic products according to country, reg. specifications, etc. (Martin 2018).	Acceleration of drug candidate evaluation Researchers at the University of Münster have developed an AI system that independently analyses all 12 million known reactions in organic chemistry. The system can discover new retrosynthetic pathways and simulate complex chemical reactions, which could revolutionise drug discovery (Hutchinson 2021, p. 632).	Digital clinical studies enable more market participants and launches
	Industry	More efficient idea generation through the use of customer/machine data Potential for improvement and new fields of application, but no new industrial processes (D-I)	The online fashion retailer Stitch Fix uses AI in product development. The AI breaks down each item of clothing into several attributes (colour, length) and combines this with customer feedback and other available data (Marr 2018)	The Indian luxury jewellery manufacturer Titan Company uses AI to test product designs (Adhikari 2017)	
	Service	Analysis of consumer behaviour for complementary services to goods			Utilisation of digital sales channels
	Energy	Focus on data coupling & making existing data usable for start-ups for further new applications			
	Smart Cities	Focus on data coupling			
	Mobility	Determination of improvement potential based on vehicle data	AI is used in quality control and accelerates product development	Acceleration (e.g. virtual MOT)	Easier target group identification
	Science	Faster retrieval of literature, suggestions for possible new research topics, input for possible innovation processes			

Figure 4: Impact of AI on the innovation process

4.5 Biggest challenges in implementing AI in innovation processes

This section looks at what respondents say are the biggest challenges in implementing AI in innovation processes.

Basically, every company has to ask itself whether AI programming skills or a fundamental understanding of AI are necessary at all. Concrete use cases are therefore indispensable - not least because the use of AI involves quite a lot of effort compared to a classic software introduction and thus also high costs, which not all SMEs can afford.

Finally, for the use of AI in innovation processes, employees must have the right qualifications and competences. This concerns both programming skills and the ability to critically classify the results of an AI, which is quickly believed without considering the ethical foundation. However, the availability of skilled workers is poor, especially in public institutions, due to the high wages paid in industry. There are also too few experts in research compared to digital companies. They also lack networking opportunities. In addition, the incentive system, which in the IT sector is often aimed at achieving results as quickly as possible, should be questioned.

Many challenges were seen in the data itself, which must be available, compatible and, above all, publicly accessible and of sufficiently high quality to be able to exploit its full potential. This requires a corresponding infrastructure among the actors. In addition, data protection must be considered for a mindful and critical handling of the data and be compatible across national borders in order to avoid data silos in Europe, the USA or China.

The acceptance of AI applications in society can also be low due to the "black box" behaviour of AI, which is why "a high level of comprehensibility" (#10, D-IV) of the decision logic of an AI is important. Another danger is seen in biased interpretations due to poor input data and the con-

tinuation or even intensification of biases. It is also unclear how informed consent for the processing of personal data is to be obtained from data owners when the ultimate use of the data is not yet known.

The contribution of AI to the common good should also be considered, as the use of AI itself also has a carbon footprint with negative environmental impacts. Here, the fundamental question was raised whether "the innovation system should remain mission-oriented or be system-oriented for the common good" (#2, D-V). In the latter case, social negotiation processes are important. For example, AI should not be used for "undesirable developments such as accelerating consumption" (#2, D-V). In this context, the previously quoted interviewee pointed out the Janus-faced nature of AI, whose applications can be beneficial for society, but can also harm it.

According to some respondents, "application-related regulatory barriers" (#5, D-II) also represent a major challenge for the use of AI in innovation processes. This relates to the fundamental question of which data may be collected at all and how the corresponding sensor technology (e.g. smart meters) can be disseminated in the market.

4.6 Need for a different innovation process to exploit AI potential

The last sub-chapter looks at whether a different innovation process than the classic concepts is needed to best exploit the potential of AI.

While one person said that AI could not generally produce innovation due to its "box" nature, because innovation is a break with the past, but machines only have historical data available (#3, D-IV), another interviewee (#6, D-I) argued that AI can support in the phases of a classic innovation process such as idea generation, the testing phase and the commercialisation phase through more simulations. Especially in the early phase, it is important to include different perspectives and reflection instead of looking at a "standard human being (white, male)" (#9 #10, D-IV) in order to take ethical and social aspects into account. In both cases, however, no adaptation of the innovation process is necessary.

Another interviewee (#13, D-III) said that instead of a linear innovation process, a problem-solving approach is needed to achieve unknown results: starting from the data that is available, an iterative and readjusting process should be used to analyse which products can be generated by AI. Creativity is needed in determining the form of data and the evaluation of results, as there is no general AI innovation process tool. Another respondent (#7, D-II) additionally pointed out that "established systems reach their limits at some point" in terms of the result horizon for new ideas, which is why a new innovation process for AI could make sense. In the case of pure efficiency improvements, AI is again only one method in the classic innovation process.

However, the use of AI in itself already represents an innovation for many companies, which requires a different introduction process than in the case of classic software projects based on requirements and specifications. In addition, there is also the fundamental question of whether the so-called "black box" should be assigned to a person for a patent that protects an invention, as is the case with classic material patents or processes. At the level of the innovation system, corresponding political framework conditions should therefore be defined for this, but also for the mandatory disclosure of data. In this context, one interviewee spoke of companies being obliged to "make data rooms available" (#11, D-VI). In addition, the question of the desire for a stronger system orientation along the lines of the common good should be mentioned again.

5 Conclusion & Next Steps

The results show that the departments have different points of contact with AI in innovation processes. Some work on industrial projects in which AI plays a role and which can be specifically located in one of the innovation phases; others, on the other hand, work mainly with ministries and in this way see how the importance of AI in the innovation sector is increasing. It came out that AI is currently used more for competitive differentiation, but in 15 years it can become the standard as a so-called basic technology and thus a factor critical to competition. As a key technology, AI can be an "enabler" for a sustainable transformation of the economy and society; at the same time, the energy-intensive use of AI will remain an immense challenge.

In a next step, the authors could mirror the results even more closely with the existing literature, identify research gaps where necessary and expand the research object to include other groups. For example, surveys or interviews with local and supra-regional (AI) start-ups would be useful to investigate the role AI plays in innovation processes today and can play in the future[2]. An additional benefit would be to better understand what drives especially SMEs and what support a research institute could provide.

[2] In this context, it is worth taking a look at a Bitkom (2022) study. In a study, the IT industry association asked 148 tech start-ups about technologies, among other things. 43% of the start-ups are currently using AI, and another 40 are planning or discussing its use.

6 List of Figures

List of Abbreviations

IT	Information Technology
KI	Artificial intelligence
SAI	Self-innovating artificial intelligence
SME	Small and medium-sized enterprise

7 List of Tables

8 Bibliography

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