Deutsches Forschungszentrum für Künstliche Intelligenz
German Research Center for Artificial Intelligence

dfki ai next

Industrial AI for Sustainability

Efficient Processes, Recycling Strategies, Resource-aware AI Models

Industrial AI for More Sustainability

Rising energy costs, a shortage of skilled workers, increasing competitive pressure, and the need to meet sustainability targets – large and medium-sized companies are being called upon to save energy, produce more efficiently, and conserve resources. This can only be achieved through the introduction of digital technologies and the use of AI. Therefore, they face a double challenge: the twin transition, which is now in full swing.

As a business-oriented AI competence center for cutting-edge research, the German Research Center for Artificial Intelligence knows and addresses this problem. Digitalization and sustainability are being strategically combined and driven forward here – with a view to the United Nations Sustainable Development Goals (SDGs). The aim is to achieve sustainability from and with AI solutions and put it into practice.

DFKI develops intelligent algorithms that optimize material flows, save resources, and pave the way for an AI-supported circular economy with economic and ecological benefits. With our top-level research and transfer mission, we see ourselves as an important driver of this transformation.

Industrial AI, with its potential for more efficient processes, reuse, and recycling strategies can significantly contribute to resource conservation. However, it‘s important to note that the deep learning models and data centers required for this are energy-intensive.

We are addressing the critical questions of sustainability in artificial intelligence itself and are researching resource-aware AI models that reduce the overall consumption of AI systems without compromising their success. This is what we call our ‘green AI approach’, which focuses on creating AI solutions that not only create economic value but also contribute to a more sustainable economy.

Prof. Dr. Antonio Krüger
CEO

Industrial AI for a Sustainable Economy

Companies in Europe, especially small and medium-sized enterprises (SMEs), are facing various operational challenges. These include competitive pressure, a shortage of skilled workers, rising energy costs, and the increasing fragility of supply chains.

Author: Dr. Christiane Plociennik

The use of digital technologies is seen as an opportunity to save resources and optimize production processes. At the latest, since large language models and applications based on them, such as ChatGPT, have become mainstream, artificial intelligence is also on everyone‘s lips as a potential enabler for improving processes and products. However, these improvements alone will not be enough in the future. Our economy must not only become more efficient but also more sustainable. The United Nations stipulates this with its Sustainable Development Goals (SDGs), and the German government is currently working on the National Circular Economy Strategy. It is due to be adopted this year. Reason enough, therefore, to look into whether AI can improve efficiency and sustainability in production and throughout the entire life cycle of products.

> « Can AI not only improve efficiency but also sustainability in production and throughout the entire life cycle of the product? »

Basically, sustainability means not consuming more resources than can be replaced, whereby there are three dimensions: ecological, economic, and social sustainability. In this sense, production is sustainable if it works resource-conserving and resource-efficiently, for example, by avoiding or reusing waste as far as possible or by incorporating used individual parts or even entire used assemblies (so-called remanufacturing). Such sustainable production also means that the products must be competitive and economically sustainable – it must simply be worthwhile to produce sustainably. Otherwise, the company will hardly be able to hold its own on the market in the long term. Social sustainability means that people should work under good conditions and be paid fairly. In the future, this should not only apply to the company itself but also to its suppliers. This is the aim of the new Supply Chain Act, which came into force in January 2024.

Towards a circular economy with AI

One way to promote sustainability is to transition from a linear economy to a circular economy. The circular economy attempts to keep raw materials “in circulation” for as long as possible, i.e., to generate as little waste as possible by reusing products, repairing them as often as possible, and recycling them as much as possible at the end of their life cycle. Reuse, repair, and recycling are three of the ten so-called R-strategies of the circular economy (see R-Graphic).

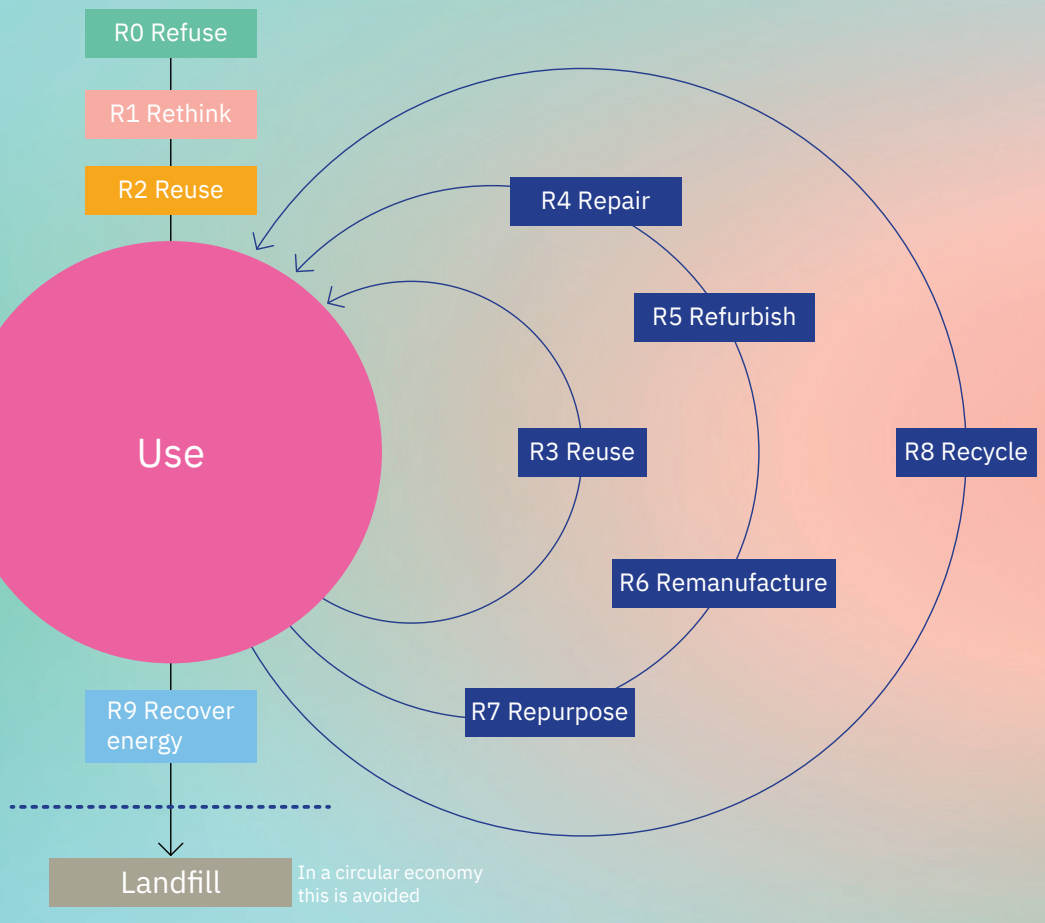
For the circular economy to work, it needs data above all – data on the product itself, the production process,

and a possible repair (e.g., repair instructions) or suitable recycling processes at the end of the product's life. This data helps the various parties involved in the circular economy: a product designer, for example, can (re) design a product with a view to improved sustainability if they know which recycling processes are possible in principle. Information on why a product cannot yet be recycled helps improve the design. The recycler, in turn, can parameterize his systems much better if he knows the composition of the products he receives. Therefore, the exchange of information between the individual players in the circular economy is crucial. But how can this be organized?

The digital product passport is the ideal solution. Starting with batteries with a capacity of over 2 kWh, this will become mandatory for more and more product groups in the EU from 2027. The exact product-related information it should contain, as well as the format and data exchange procedure, has not yet been finalized. One of the purposes of the product passport is to create the transparency required by the Supply Chain Act. However, it is also suitable for implementing the →

Circular economy R-ladder

R-Graphic: The ten R-strategies for circular value creation.



R-strategies of the circular economy with the help of AI. DFKI is also researching this.

DFKI tests the digital product passport

DFKI is implementing various product passport concepts as prototypes in its research projects.

In the **CircThread** project, DFKI and 30 other European partners are exploring the possibilities of the digital thread concept, a kind of digital thread across the entire product life cycle. In an information system, it is not the information about a product itself that is stored but where it can be found. This information can then be used at the end of the life cycle to decide what to do with the product – is it worth remanufacturing, or should the product be recycled?

The Digital Lifecycle Passport (DLCP), a product passport based on the Asset Administration Shell, was designed and implemented in the **ReCircE** ("Digital Lifecycle Record for the Circular Economy") project. The DLCP enables role-based access to product information. It can be read by both humans and machines. This means that the information can be displayed user-friendly via a web application but can also be used to control machines. This was also implemented in the ReCircE project: combined with AI-based object recognition, the information from the DLCP is used to control a sorting system. The result is a hybrid AI system that sorts e-waste according to innovative sorting criteria – for example, whether a device is potentially dangerous because it contains a battery. Such a device should be sorted out before recycling to prevent it from catching fire. This approach can, therefore, improve the sorting and recycling process for old electrical appliances.

The digital product passport is also an essential topic for the **Green-AI Hub Mittelstand**. The Green-AI Hub Mittelstand is an AI initiative of the Federal Environment and Consumer Protection Ministry, coordinated by Zukunft Umwelt Gesellschaft gGmbH and implemented by DFKI. The Green-AI Hub Mittelstand helps companies use modern AI solutions for greater resource efficiency. At the heart of the Green-AI Hub are 20 AI pilot applications, each of which will be implemented at pilot

The Digital Lifecycle Passport (DLCP) enables role-based access to product information. It can be read by both humans and machines.

SMEs over a period of six months. The applications cover a wide range of topics, from optimizing logistics and the use of goods in the skilled trades to digitally integrated solutions for plant maintenance or closing material flows in industry.

To make the topic of "AI for resource efficiency" tangible for interested companies, a mobile demonstrator was developed as part of the Green-AI Hub Mittelstand. The demonstrator clearly shows how companies can integrate the R-strategy "Reuse" into their production.

The quality control and storage of used parts are shown using the example of a model truck. To do this, an AI-based optical quality control system first assesses the condition of a used product and sorts it into one of four quality categories on this basis. A price is then determined for the used part, the potential CO2 savings are predicted, and a storage space is reserved in the connected parts warehouse. All this information is stored in the truck's digital product passport and published via a digital marketplace. Potential customers and manufacturers can access the information via this marketplace and decide whether used parts should be installed in a new truck to be produced. These can then be ordered as required and taken from the parts warehouse for the new production process. DFKI is thus expanding its demonstrator landscape to include the topic of the circular economy and bringing it to Hannover Messe 2024.

A look into the future of the circular economy

With CircThread, ReCircE, and the Green-AI Hub, DFKI demonstrates how the interaction between the circular economy and AI works. However, there is still a lot of

research to be done, as the data situation in the circular economy is currently still patchy. There is often a lack of information at key points to enable decisions to be made – by AI or by humans. The relevant community also does not yet have sufficient expertise to harness and analyze the appropriate data. This is where the Data Competence Center for Circular Economy Data – **DACE** for short – comes in. It brings together computer science and AI researchers from different universities and institutions with experts in the circular economy and life cycle assessment so that everyone can learn from each other. The first step is to understand where data still needs to be added and in what format it needs to be available. Procedures are then collected and tested in order to create comprehensive sustainability assessments from this data, e.g., AI-based analyses for specific products. Ultimately, scientists, companies, and the general public should benefit from these findings. This brings the AI-based circular economy a good step closer to the mainstream.

www.green-ai-hub.de
www.recirce.de
https://circthread.com

The mobile demonstrator of the Green-AI Hub Mittelstand shows how companies can integrate the R-strategy „Reuse“ into production.

Resource-saving AI Through Energy-efficient Algorithms

Interview with Prof. Dr. Wolfgang Maaß

Every question you ask ChatGPT has its price. Every time you develop and use AI, you leave an ecological footprint. In this interview, Wolfgang Maaß explains whether artificial intelligence can be sustainable and which indicators need to be met for this to be the case. He is a professor of business administration, particularly business informatics in the service sector, and head of DFKI's Smart Service Engineering research department. He is currently coordinating and leading the ESCADE project, in which a consortium of numerous partners is researching energy-efficient data centers.

How high do you estimate the potential for energy savings through resource-saving artificial intelligence?

The power consumption of the Internet is still relatively low compared to other industries and sectors, but it is rising steadily. In Germany alone, the internet consumes around 13 TWh per year, corresponding to the consumption of all private households in Munich. The CO2 emissions are about as high as air traffic or steel production. From a global perspective, the electricity consumption of data centers is expected to double from 460 TWh in 2022 until 2026. Considering that the essential services of the internet are now based on AI, there is enormous potential for savings here. We can tap into this if we make AI-based services on the internet significantly more efficient. Developing new concepts for the climate-neutral Internet is at least as relevant as research into electric and hybrid drives and the potential uses of green hydrogen.

It is a known fact that data centers are energy-hungry. Many companies are relocating their centers to colder regions to save on electricity costs for cooling. Does this make operations more sustainable?

The operator reduces the electricity consumption for cooling but the heat is still generated. We are currently unable to use this energy sensibly, so we are heating up the environment instead. The multidisciplinary team in the ESCADE research project wants to get to the root of the problem and is researching more energy-efficient algorithms and hardware.

The ESCADE project is a medium-sized project

funded by the Federal Ministry for Economic Affairs and Climate Action, with a volume of around 5 million euros. What is unique about it?

Compared to the resources that big technology providers can spend, that's a little. However, more money does not necessarily mean more success. When it comes to providing a proof of concept, a small team can be just as successful. ESCADE is not just a project on resource efficiency but also a resource-efficient project that follows the guidelines of frugal innovation. It is also a full-stack project that considers all components from algorithmics to implementation, including chip design, chip production, and the use case in an integrated manner. Furthermore, the entire technology stack is in German hands.

DFKI's contribution to the project is the algorithms. What role does software play in improving the energy balance of data centers?

Software design can start with the selection of large language models. It doesn't always have to be GPT-4. For specialized tasks, you can also work with smaller models derived from larger ones. Not all computing operations have to be carried out on mainframes, but they can also be trained and executed on edge close to the application. The focus of our considerations is the question of which AI algorithms we can use to come closer to the economic functioning of the human brain in terms of design. The concept of neuromorphic computing, which makes it possible to switch areas of the chip on and off depending on the computing task via algorithmic control, is very promising here.

You said ESCADE addresses the entire technology stack from the chip to the use case. What does this look like?

One application example is the use of visual computing to efficiently sort steel scrap for recycling using a distributed architecture that tests and evaluates various AI models and scenarios in terms of their energy efficiency. Using a drone and an NVIDIA Jetson board, we classify steel scrap on the site of a steel mill on-edge and in real-time, enabling more informed decisions on how to recycle the scrap steel.

At the same time, energy profiles are created to measure the energy consumption of the AI application and compare it with the positive sustainability effects of the application and other scenarios. Using optimized hardware with highly efficient AI algorithms, we are trying to create a mobile environment that delivers maximum performance with minimum energy input.

What usable results can the economy expect?

We hope ESCADE will become a pioneering concept for resource-efficient data centers and AI use cases with proven business sustainability. To make this measurable, ESCADE is developing a framework model for measuring the sustainability of AI systems. This will provide the German economy with a model for balancing AI energy consumption.

https://escade-project.de

Edge Devices in Production

From small power guzzlers to efficient AI systems

Agriculture, healthcare, transport and logistics, the Internet of Things (IoT), production, and manufacturing – wherever fast data processing and real-time decisions are required, specialized, compact hardware is used on-site. In industrial production, edge devices record and analyze sensor data or detect faulty products. They promise lower latency times and complete control over locally processed data. Edge computing is booming: studies predict that the Internet of Things will grow by more than 16% by 2028. Data processing on-site already offers a certain savings potential per se: No energy has to be used to transfer the data to the data center and retrieve the results from there. But there is more to it.

Frugal AI is the name of the concept for economical artificial intelligence, which aims to reduce power consumption for peripheral computing by using less memory, less computing power, and more data efficiency.

The French computer science institute Inria (Institut national de recherche en informatique et en automatique) and DFKI are working on this in the **FAIRe** project. The project itself is a particular case: it is funded by the research ministries of both countries as part of the Franco-German cooperation in the field of AI. FAIRe (Frugal Artificial Intelligence in Resource-limited environments) aims to enable the deployment of AI applications on mobile devices through an innovative approach to reducing the model size and computational effort through network quantization, optimization of the network architecture, optimization of the computational flows, and, finally, network execution on low-power high-performance hardware.

„Our goal is to develop a comprehensive approach that addresses the different layers of implemented, running AI systems. To do this, we consider all levels of abstraction of an AI application: The actual AI algorithms, the hardware, and the compiler layer in between, which is responsible for the efficient translation of the algorithms to specific hardware," explains Prof. Christoph Lüth, who is leading the project on the DFKI side.

A case study will demonstrate the practicality of the approach. The interaction between a human and a robot will be used to illustrate how the various layers of abstraction work together and how adaptation to unknown contexts and continuous robotic learning can also succeed in a resource-conscious manner.

Human-Centric AI

Intelligent Solutions for the Knowledge Society

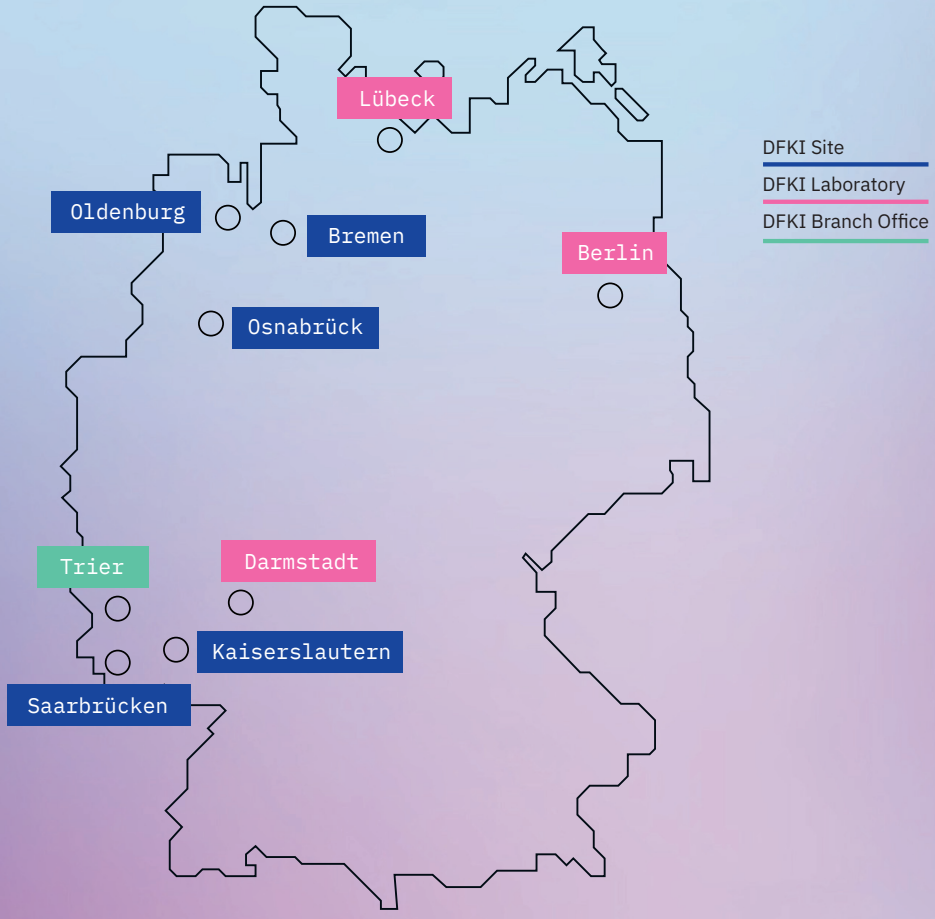
DFKI has been researching human-centric AI for over 35 years, focusing on social relevance and scientific excellence in the key future-oriented research and application areas of artificial intelligence.

The German Research Center for Artificial Intelligence (DFKI) was founded in 1988 as a non-profit public-private partnership. It has locations in Kaiserslautern, Saarbrücken, Bremen, Lower Saxony, laboratories in Berlin, Darmstadt and Lübeck as well as a branch office in Trier.

In 26 research departments, ten competence centers, and eight living labs, product functions, prototypes, and patentable solutions in the field of information and communication technology are developed on the basis of application-oriented basic research. Financing is provided through public funding and development contracts from industry.

Project results and milestones are periodically reviewed institutionally and by an international panel of experts (Scientific Advisory Board). In addition to the federal states of Rhineland-Palatinate, Saarland and Bremen, numerous renowned German and international high-tech companies from a wide range of industries are represented on the DFKI Supervisory Board.

www.dfki.de



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