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RENEWABLE ENERGY AND SUSTAINABLE DIGITALISATION: CHALLENGES FOR EUROPE

Abstract: The key to a successful strategy for Europe is sustainable innovation. The current political, economic and military crisis should be used to accelerate the shift to sustainable innovations in order to exit the path dependency of fossil energies. Such as diversity of portfolios at stock markets, diversity of energy and digital technologies ensures resilient behaviour in an innovation portfolio to respond flexibly to the risks of the future and to recover overall in the event of selective setbacks. Sustainable technologies must not be based on a single solution, but rather the entire technological potential must be bundled in an innovation portfolio. A case study is presented in which energy-efficient digitalisation is linked to a sustainable circular economy. A democratic legal system is not only an expression of the human rights highlighted in the UN Charter, but also provides a certain and reliable legal framework for innovations and markets on which technological and economic competition takes place.

Keywords: renewable energy, sustainability, digitalisation, path dependency, innovation portfolio, hybrid IT-systems, digital circular economy

Introduction

Against the background of the current ecological, economic, political and military world situation, it becomes glaringly obvious what has been seriously lacking in the recent past - strategic thinking. The era of visual flight and short-term political and economic interests led to disaster. Others seized the moment for their long-term strategies and interests. What can we do on the part of science, research, education and training? Answer: Learn to think strategically, because only on this basis can responsibility be implemented.

The key to a successful strategy for Europe is called sustainable innovation. People tend to prefer not to leave familiar and hitherto successful development paths than to focus on new innovation. Success and profits lead to a feedback loop of self-reinforcement of entrenched processes, so that stakeholders become blind to changes in the ecological, economic, and political environment. The economists Brian Arthur and Joseph Schumpeter spoke of "path dependency" in this context [1].

This "path dependency" is dramatically demonstrated in the recent past, when those responsible in politics and business brought European countries (e.g., Germany) into the energy policy dependency of essentially one country. The proven profits from fossil fuels such as gas, oil and coal were tempting, although there was no lack of strategic warnings

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against blind trust in the dominant supplier. But every small shareholder knows that one should never rely on a single equity line, however tempting it may be in the short term. A good portfolio is characterised by diversity and variety in order to make a good long-term cut despite all crises.

The thesis is therefore that the pressure of the current political, economic and military crisis should be used to accelerate the shift to sustainable innovations in order to exit the path dependency of fossil energies. This is to solve the real big problem of this planet - the global environmental and climate crisis (Section 2). As in politics, however, the focus must not be on a single solution, but on bundling the entire technological potential in an innovation portfolio.

Future technologies, like shares, are also bets on the future. For this purpose, the advantages and disadvantages of e.g. solar and wind energy, hydropower, hydrogen, nuclear and fusion energy must be weighed against each other for Europe and combined in a "hybrid" energy system in order to orient the European innovation portfolio towards a sustainable future (Section 3). Diversity also ensures resilient behaviour in an innovation portfolio to respond flexibly to the risks of the future and to recover overall in the event of selective setbacks.

Energy supply chains are just one example of complex networks of modern civilisation whose vast amounts of data and information cannot be managed without digitalisation and artificial intelligence (AI) (Section 4). However, digitisation requires a huge amount of energy, which differs for different computer technologies. As in the energy issue, digitisation must not be based on a single solution, but rather the entire technological potential must be bundled in an innovation portfolio. Therefore, classical digitisation and artificial intelligence together with future technologies such as neuromorphic computing (following the energy-saving mode of natural brains) must be considered as well as quantum computing, quantum communication and quantum technology. For this purpose, advantages and disadvantages of digital and analogue technologies must be weighed against each other for Europe and combined in a "hybrid" IT and AI, so that this European innovation portfolio is also oriented towards a sustainable future together with the energy issue.

An innovation portfolio is made up of basic, bridging and future technologies that need to change, be abandoned and replaced by new ones in the short and medium term. An innovation portfolio is therefore dynamic and must be constantly shaped. Methodologically, this is done by drawing on the mathematical theory of complex systems and non-linear dynamics, which can be used to model complex systems and networks in nature, the economy and society and which the author has been working with for decades. On this basis, chaos and risks become assessable in early warning systems and convertible into strategic action.

In Section 5, a case study is presented in which energy-efficient digitalisation is linked to a sustainable economic system. A sustainable circular economy can only be realised through support with digital tools due to the immense amounts of data.

However, the recent political, economic and military crisis also shows that strategic thinking and action cannot be limited separately to individual branches of research, technology and business. Innovation strategies are in global conflict with political world systems. Innovation systems are an expression of different value systems in, for example, the USA, Russia, China and Europe (Section 6). The free democratic constitutional state is not only an expression of the human rights highlighted in the UN Charter, but also provides legal certainty for innovations and markets on which economic competition takes place.

1. Energy technology and sustainability

Key sectors for the future of Europe are energy and information technology. On 24 February 2022, the state of Europe was revealed when the Russian Federation broke international law and invaded the sovereign state of Ukraine. Public awareness of massive dependence on Russian imports of fossil fuels such as gas, oil and coal was brought into sharp focus. In, e.g., Germany 2021, it accounted for 55 % of gas imports, almost 50 % hard coal and 35 % crude oil. If, for example, the gas supply were to come to a complete standstill, the chemical industry would be deprived of a basic supply. However, the chemical industry is at the beginning of many production chains in the national economy. An interruption at this sensitive point could therefore trigger a chain reaction in the sense of complex system dynamics, which would build up to global collapses of the entire economic system.

Instead of unilateral dependence, the first step is therefore to achieve security of supply with fossil fuels through diverse suppliers and providers. In short, it is about replacing monopolies of supply with diversity. Liquefied natural gas (LNG) lends itself to this, as this form of energy can be transported worldwide from different countries and continents by ships to central liquid gas terminals in European locations.

In addition to securing raw materials, the stability of energy networks must be ensured. An energy grid is a typical example of a complex dynamic system that is usually non-linear with many interactions of the supply nodes [2]. To be able to cope with an unforeseen failure in individual sub-areas, redundancies should be built in and resilience strategies should be considered. Resilience in a complex dynamic system means that temporary disturbances of the equilibrium can be absorbed and the system returns to its equilibrium by itself after a certain time. Redundant supply chains can absorb temporary failures and enable resilience. Electricity storage and demand must be sufficiently flexible to compensate for supply and demand fluctuations.

However, fossil fuels are only bridges towards a sustainable energy supply. Under the impact of the Ukraine war, European countries have already announced their intention to achieve 100 % electricity generation from renewable energies - the 24 February 2022 as a catalyst for an accelerated innovation dynamic. On the one hand, the expansion of renewable energies is a question of financial incentive for investors, who have to decide which advantages and disadvantages various remuneration models for these energies entail [3, 4]. In the short term, however, the cumbersome and lengthy planning and approval procedures are a considerable obstacle to the rapid introduction of renewable energies. To this end, the legal framework must be reformed in the short term.

In addition, there are characteristics of renewable energies that make a balanced overall energy supply network difficult. Renewable energies with wind and solar plants are weather-dependent. Energy production therefore fluctuates and can only be regulated and calculated to a limited extent. In addition to the high initial investment costs, there is also an investment risk with wind or solar plants, for example, which can influence the cost structure with high marketing prices through risk premiums. Such and other feedback effects lead to complex system dynamics that need to be carefully examined [5]. One instrument to control the innovation dynamics are market premiums, which are set through tenders. To guarantee greater price certainty, minimum and maximum prices for emission certificates can also be set. Here, however, national unilateral action is not sufficient; instead, embedding in a comprehensive EU emissions trading system is necessary.

24 February 2022 thus underlines the urgency of developing a European supply network according to the laws of complex system dynamics and the demands of sustainability [6]. In addition to the renewable energies already available, such as solar, wind and hydro, hydrogen, nuclear and fusion energy must also be considered in an overall European perspective. In the end, Europe will need a hybrid network of these technologies to maximise sustainability and independence.

2. Hybrid energy systems as sustainable innovation portfolio

Each of the existing forms of energy has advantages and disadvantages that need to be weighed against each other. In the end, it will come down to a balanced portfolio that best takes into account the demand situation and future contingencies. Natural gas, due to its lower CO_2 emissions compared to oil, is an important source for the transition to the development of viable alternatives.

Renewable energy should be used as much as possible, but without forgetting that for any energy source to be considered a major source, it must be abundant and reliable. At the same time, hydropower will be an important resource in the coming years. The development of technologies to promote biofuels, biomass or techniques such as waste to fuel is also being promoted.

In countries like Italy, about 30 million tonnes (tonne = 10 Mg = 10^6 g) of waste are generated every year, of which 14 million tonnes are correctly separated. Of these, about 7 million tonnes are OFMSW (Organic Fraction of Municipal Solid Waste) [7]. Currently, it is mainly used to produce compost for agriculture and, to a lesser extent, biogas. A combination of well-separated waste management and more waste-to-fuel plants across Italy could produce about one billion litres of bio-oil annually, equivalent to about 6 million barrels of crude oil per year.

Hydrogen, especially green hydrogen, will play an important role as a bridging technology in the coming years [8-11]. However, this will require research and innovation to bring costs down. Nuclear energy has an advantage: it can supply large amounts of energy constantly (24 hours a day) and in a controllable way. This would be possible even under extreme conditions, such as those found in space or in the deep sea. Hydroelectric and geothermal plants can supply energy continuously under earth conditions. However, they require special territorial conditions that not all countries have.

To better understand the importance of nuclear energy, it is necessary to understand how the demand for electricity is structured. Production must be able to guarantee grid stability. Demand fluctuates considerably during the day: it reaches its minimum at night, increases during the day and usually peaks before dinner. Electricity consumption can therefore be divided into two parts: a constant consumption that is present at every hour of the day (base load) and only consumption during peak hours (peak load). Most of the technologies that carry the base load today are fossil fuel power plants that need to be gradually replaced to meet the emission reduction target.

It would stand to reason that renewable energy sources such as wind and solar could be a good substitute. However, relying on them all over the world would also bring technical difficulties: The wind does not always blow in different regions of the earth, the sun fails at night or the sky has different cloud cover. Since these are therefore fluctuating sources that can only be predicted to a limited extent, storage systems for energy are necessary and/or complementary technologies that are able to compensate for a possible drop in production quickly and without CO_2 emissions.

An energy system with a high share of variable renewable energy would increase energy costs for individuals and industry. Therefore, if the goal is to reduce emissions where large amounts of hydropower and geothermal energy are not available, nuclear energy promises to be an efficient solution to replace fossil fuel power plants in the production of base-load energy. The prerequisite, however, is that the risks of nuclear power plant operation are manageable with the storage problems of nuclear waste [12].

Nuclear energy is to be considered worldwide not only for the achievement of climate goals, but also with regard to the reliability of national energy systems. Looking ahead to 24 February 2022, it reduces a country's dependence on energy imports to meet its energy needs. Waste disposal remains a central problem. But here, too, a differentiated assessment is necessary, taking into account the diverse types of reactors and their respective technologies and innovations [13].

Finally, Europe must find an overall portfolio for sustainable energy production and supply. Such an overall portfolio with its various initial, bridging and future technologies is in constant flux, depending on the state of development of the individual sub-technologies. We therefore also speak of a dynamic innovation portfolio. At the national level, the different geological, climatic, economic and political conditions must be taken into account. The diversity of highly mature energy innovations could prove to be a locational advantage. It is noteworthy that there is complete acceptance of fusion reactors as a future technology throughout Europe [14-16]. Indeed, this would be the ultima ratio, to be able to produce "solar energy" on an unlimited scale, largely without waste and risk on earth.

Achieving the climate goals would theoretically be possible without further investment in nuclear energy. However, excluding this energy source from the overall portfolio would require a much greater mobilisation of other resources. If it were decided between now and 2040 to stop investing in nuclear energy, the missing electricity generation would have to be compensated by an amount of wind and solar energy equivalent to five times the total capacity installed worldwide in the last 20 years [17].

In the end, it is a matter of a complex energy system that is diverse and multifaceted, has sufficient redundancies to compensate for local failures, and responds resiliently to disruptions in order to stabilise itself again afterwards. The interactions of bridging technologies and renewable energies must be well interconnected in a hybrid system to achieve sustainable development dynamics. Finally, the supply systems must be controllable by an intelligent "nervous system" as in a complex organism. This is achieved by the key technologies of information and communication technologies, which will now be discussed.

3. Information technology and sustainability

Information and communication networks are the background of a worldwide automation through artificial intelligence. In the future, enormous computer capacities will be necessary to cope with the huge amounts of data of this civilisation. The complexity of life, its misunderstood interrelationships, its sensitivity and vulnerability, which is evident in diseases such as cancer as well as in viral pandemics, requires new tools in life sciences and medicine. Here, bioinformatics will increasingly have to rely on machine learning and suitable computer and storage capacities. The same applies to the management of global financial and economic crises, which require early warning systems. Thus, information and communication networks are converging with the big other high-tech hype, artificial intelligence.

The digitalisation of human civilisation requires a tremendous amount of energy. Computer technology and information and communication networks cannot therefore be seen separately from the energy consumption of this civilisation. At the same time, this highlights the ecological dimension of digitalisation, as fossil energies are a burden on the environment. What can we learn from nature, which has produced extremely effective and energy-saving brains and nervous systems in evolution? This is where neuromorphic computing comes into play, whose computer architectures are modelled on the brains of evolution. Instead of energy-guzzling von Neumann architectures of classical computers from smartphones and PCs to supercomputers, computing units are now used that still work on hardware but according to the efficient methods of neurons and synapses in brains. Instead of total digitisation, they also use the advantages of analogue processes as known from living organisms.

After electrification and digitalisation in the 20th century, the quantisation of communication and supply networks is now on the agenda. This is happening gradually and not "disruptively". The universal quantum computer will also not "disruptively" replace classical computer technology, but will increasingly be embedded in classical and neuromorphic computer structures and solve new tasks that were excluded with these methods. There is already talk of "ecological" and hybrid computer networks gradually spreading across the world [18].

Turing's definition of Artificial Intelligence

Traditionally, AI (artificial intelligence) has been conceived as a simulation of intelligent human thought and action [19]. According to the definition of the British computer pioneer and logician Alan Turing (1950), a system should be called "intelligent" if it cannot be distinguished from a human in its responses and reactions by a test subject.

Symbolic AI: logic and deduction

Intelligence is traditionally associated with logical thinking and problem solving. In an initial phase, AI was therefore oriented towards formal (symbolic) calculi of logic, with which solutions to problems can be derived in a rule-based manner. This is why we also speak of symbolic AI. A typical example is automatic proof with logical deductions, which can be realised with computer programmes. Automation also means autonomy to a certain degree, since computer programmes take over the proof activities of a mathematician. Knowledge-based expert systems are computer programs that store and accumulate knowledge about a specific field, automatically draw conclusions from the knowledge to offer solutions to concrete problems in the field. Unlike human experts, however, the knowledge of an expert system is limited to a specialised information base without general and structural knowledge about the world [20].

To build an expert system, the expert's knowledge must be put into rules, translated into a program language and processed with a problem-solving strategy. The architecture of an expert system therefore consists of the following components: Knowledge base, problem-solving component (derivation system), explanation component, knowledge acquisition, dialogue component. In this architecture, the limits of symbolic AI become clear at the same time: abilities that cannot or can only with difficulty be captured symbolically and simulated rule-based remain closed to symbolic AI.

Subsymbolic AI: statistics and induction

Sensory and motor skills are not logically derived from textbook knowledge, but are learned, trained and practised from examples. In this way, we learn to move motorically and to recognise patterns and correlations in a multitude of sensory data, which we can use to orient our actions and decisions. Since these abilities do not depend on their symbolic representation, we also speak of subsymbolic AI. The formal conclusions of logic are now replaced by the statistics of the data. In statistical learning, general dependencies and correlations are to be deduced from finitely many observational data by algorithms [21]. Deduction in symbolic AI is thus replaced by induction in sub-symbolic AI. For this purpose, we can imagine a natural science experiment in which a series of changed conditions (inputs) are followed by corresponding results (outputs). In medicine, it could be a patient who reacts to medication in a certain way.

Learning with neural networks

Neural networks with learning algorithms play a key role in the automation of statistical learning [22]. Neural networks are simplified computational models of the human brain in which neurons are connected with synapses. The intensity of the neurochemical signals sent between the neurons are represented in the model by number weights. Probabilistic networks experimentally bear a strong resemblance to biological neural networks. If cells are removed or individual synapse weights are changed by small amounts, they prove to be fault-tolerant to minor perturbations, as the human brain is, for example, in the case of minor accidental damage. The human brain works with layers of parallel signal processing. For example, between a sensory input layer and a motor output layer, there are internal intermediate steps of neuronal signal processing that are not connected to the outside world.

Artificial neural networks are extremely effective for processing complex problems (real world problems). What is missing, however, are specifications and standards for the safety of their outputs. For this, the black box of neural networks must be better understood, controlled and verified [23]. However, the verification of neural networks is a hard knowledge problem: even the proof of simple properties turns out to be NP-complete in the context of complexity theory. The reasons for this are the size of the practically applied networks (scaling) and the non-linear activation functions of their neurons, which cannot be comprehended by humans on this scale and at this speed. Since neural networks are also subject to the dynamics of complex systems, they are often sensitive to small disturbances and changes in their inputs, which can build up to uncontrollable effects. The robustness and stability of the networks is therefore closely related to their security.

AI-Systems as service systems

However, AI programmes are now not only appearing in individual robots and computers. Algorithms capable of learning already control the processes of a networked world with exponentially growing computing capacity. Without them, it would be impossible to cope with the flood of data on the internet, which is generated by billions of sensors and networked devices. So because of the sensors, things are now communicating with each other and not just people. This is why we speak of the Internet of Things (IoT) [24].

In medicine and the healthcare system, large hospital centres are examples of such complex infrastructures, whose coordination of patients, doctors, medical staff, technical devices, robotics and other service providers would no longer be controllable without IT and AI support.

The safety-critical challenges that have just been discussed will become even more acute in such infrastructures. Beyond that, however, there is the question of the role of humans in a more or less automated world. I therefore advocate technology design that goes beyond technology assessment. The traditional view of simply letting the developers work and assessing the consequences of their results at the end is not enough, based on experience. In the end, the child may have fallen into the well and it is too late. It is true that innovation cannot be planned. But we can set incentives for desired results. Ethics would then not be a brake on innovation, but an incentive for desired innovation. Such an ethical, legal, social and ecological roadmap of technology design for AI systems would correspond to the basic idea of the social market economy, according to which a scope for competition and innovation is set. The benchmark remains the dignity of the individual human being, as laid down in the Basic Law of the Constitution as the supreme axiom of parliamentary democracy.

This ethical positioning in the global competition of AI technology is by no means self-evident. For the global IT and AI corporations of Silicon Valley, it is ultimately about a successful business model, even if they promote IT infrastructures in less developed countries under terms and conditions they dictate. But the other global competitor is China, which strictly follows a state monopolism in the Silk Road project [25]. The Chinese Social Core project is closely linked to the ambitious goal of producing the world's fastest supercomputers and most powerful AI programmes. This is the only way to realise the Social Core with total data collection of all citizens and their central evaluation.

Total state control of private data may shock Western observers, but it is accepted in wide circles of China's population. The reason is, on the one hand, greater efficiency in solving global threats such as epidemics. This includes direct access to all kinds of medical data for medical research. In addition, there is another tradition of values that has been practised in China for centuries: In that country's Confucian tradition, the supreme standard of value is collective harmony and security, rather than the autonomy of the individual with enforceable rights to freedom [26].

The proclamation of individual human rights is deeply rooted in the philosophical tradition of European democracies. We do need certified AI algorithms as a reliable service for coping with the complexity of civilisation. However, it is also crucial to strengthen human judgement and value orientation so that algorithms and Big Data do not get out of hand. In the global competition of AI systems, we should be able to shape our lives according to our own values.

4. Hybrid IT systems as sustainable innovation portfolio

Each technology has advantages and disadvantages that need to be weighed against each other. In addition, technologies prove to be bridges to new and more efficient solutions. They are therefore always "bridging technologies". In such a situation, it would be extremely unwise to bet only on an existing technology or to hope for the future. As with shares, it is important to network a portfolio of different technologies in order to have a good cut in case of failures and misjudgements of individual parts. Such an innovation portfolio is also in dynamic change and needs to be maintained and cared for.

Hybrid AI = symbolic AI + subsymbolic AI

A dynamic innovation portfolio is required for energy technologies, as shown in the previous sections, but also for computer technologies and the information and communication systems based on them with artificial intelligence. Subsymbolic AI aims primarily at pattern recognition, as it occurs in organisms in perceptual processes, while symbolic AI maps the logical thinking and reasoning of the human mind (e.g. in expert systems). The combination of both approaches is called hybrid AI and thus comes closer to human intelligence than the reduction to one of the two approaches [27].

Hybrid computing = Classical computing + Quantum computing

A hybrid connection is also desirable for classical computing from smartphones and PCs to supercomputers with quantum computing [28]. Quantum computing, when mature, will not "disruptively" replace classical computing. Rather, the functions of quantum computing will be embedded in classical mainframe computers to solve typical tasks in conjunction with classical procedures. Because of the tremendous increase in computing speed, tasks with enormous amounts of data will come into consideration (e.g. climate models, traffic models, brain simulation, elementary particle physics, galaxies, etc.). This also applies to the already existing D-Wave computers, which are not based on circuits with quantum logic gates like quantum computers, but solve optimisation tasks through adiabatic computing as in thermodynamics. The difference to classical adiabatic computing is that thousands of quantum bits are already used, albeit simulated on conventional mainframe computers. So it is again about solving special tasks ("optimisation tasks") with special methods ("adiabatic computing with quantum bits") embedded in classical computer systems.

Hybrid computing = Analog computing + Digital computing

Before universal programmable digital computers laid the foundation for modern digitisation in the 1940s, analogue computers were used, which were also designed to solve specific tasks. The idea of analogue computers is ancient [29]: For example, a technical-mechanical model ("analogue") of the physical planetary system was built to determine constellations of the planets. As early as the first century B.C., Greek mathematicians had presented such an analogue computer with the mechanism of Antikythera, which could perform such calculations by adjusting a gear mechanism for assumed celestial spheres. With the advent of electrical engineering, tubes, transistors, etc. could be used to realise computational tasks. In the case of a differential or integral equation, the arithmetic operators, e.g. multiplying, adding, integrating, differentiating, were represented by corresponding ("analogue") electrotechnical units and technically connected with each other to solve the task. The mathematical equation can be understood as a circuit diagram for the analogue technical-physical model with which the solutions are calculated.

An analogue computer therefore needs a large number of computing elements to represent all the different operations, quantities and links in tasks "analogue". In contrast, a digital computer needs only a few computing units, which must be processed extremely quickly one after the other with very simple commands. It is the bits 0 and 1 with a few operations of adding, subtracting and multiplying bits that can be linked in a few logical gates to form highly complex circuits. For an addition task, a digital computer must first read the bit sequence for the command "Add" from a memory and execute it. The addends must also be read from a memory as bit sequences before the operation is performed on the addends.

All of this costs time and energy, which is multiplied by millions and millions of calculation steps for individual bits. An analogue computer does not need a von Neumann architecture with separate memory, control and computation units and sequential execution of instructions in algorithms and programmes, but solves the tasks "directly" in an electronic model.

From today’s perspective, analogue computers are therefore energy-efficient and time-saving, but limited to special applications that can be represented, for example, in differential and integral equations. These are mainly special tasks from engineering and natural sciences, for each of which an analogue computer model must be produced. Mathematically, such equations use real numbers such as decimal fractions (e.g. $\pi = 3.1415...$) with arbitrary ("infinitely small") quantities and continuous processes, in contrast to digital numbers such as the two bits. Analogue computing therefore also refers to computing with real numbers [30].

In the 1970s, it initially seemed that digital computers would replace analogue computers because of their universal applicability in all possible fields. Because of the tremendous speeds of digital computers from smartphones to supercomputers, the typical tasks of analogue computers also seemed to be simulatable. From the point of view of energy efficiency and environmental protection, analogue computers are now moving back into the centre of interest.

Hybrid computers are now also understood to be the coupling of digital and analogue computers [31]. The analogue computer is used as a powerful co-processor for the digital computer. However, this also requires software to be able to program the analogue computer in the computer environment of the digital computer. Similar to the functions of a quantum computer, analogue computers are embedded in a digital environment to solve special tasks. One also speaks of "ecological" computer systems, meaning the diverse networking of computer types.

Hybrid robotics = Embodied robotics (”Embodied mind”) = Analog robotics + Digital robotics

In robotics, too, digital and analogue functions are combined as in an organism. Cognitive and intellectual abilities cannot be mapped in software that is separate from the body. In order to recognise connections and structures, experience is required through perceptual processes with sensory organs and experiencing movement sequences with organic motor functions such as hands and fingers. In cognitive psychology and cognitive philosophy, we speak of the "embodied mind": the human "mind" is not isolated, but "embodied" in the organism. Many physical processes take place in analogue form via sensors, while control and steering functions are more digital. Humanoid robots are increasingly being developed along the lines of "embodied mind" in hybrid coupling of analogue and digital functions.

Analogue functions modelled on the brain also come into play in neuromorphic computing. Biological brains are by no means digital switch boxes in which neurons "fire" and "non-fire", i.e. digitally switch back and forth between two states as bits 0 and 1. Rather, synaptic connections have analogue components, as they continuously and gradually take weights into account. In neuromorphic computing, analogue components are connected with digital components in memristive and photonic neural systems for this purpose [32]. However, the hardware of neuromorphic systems is realised with silicon and nanotechnical materials and not with living tissue ("wetware") as in biological brains. On the one hand, this hardware is certainly more robust and cannot be attacked by diseases like biological tissue. Also, performance increases and permanent loads are possible, which living tissue cannot withstand, up to and including the fatigue of natural brains.

Hybrid IT systems with humans und computers

In the dynamic innovation portfolio, therefore, people with their creative abilities must not be forgotten. Hybrid IT systems therefore also refers to the coupling of people with algorithms and humans. While algorithms can process gigantic amounts of information in a flash with extreme precision, humans are usually more creative and are characterised by both intuition and empathy in dealing with their environment. Decisions should still ultimately lie with the human being. But when an experienced pathologist can draw on thousands of examples when assessing tumours in tissue sections, but learning algorithms in Deep Learning can draw on millions of examples at lightning speed, things seem to get tight for humans.

A human expert should be able not only to state his diagnosis, but also to justify explanations and trade-offs. This explanatory component must also be demanded of algorithms (explainable AI). In the example of medicine, such explanations must ultimately be court-proof. Here, the limits for an algorithm become clear if there is no prior and background legal knowledge. Therefore, final decisions and the associated responsibility for humans are mandatory in high-risk and explosive situations such as in medicine.

Information exchange between humans and machines (algorithms) is required in hybrid systems. Humans thus learn from the machine and vice versa. This creates feedbacks of learning between two sides that complement each other. The example of medicine makes it clear: in the final decision, e.g. of a therapy application for cancer, not only questions of the exact tumour determination and possible feedbacks with other diseases of the patient have to be taken into account, but also psychological and social, legal and economic factors of the quality of life, which are not (yet?) realisable for an algorithm. Even if it were possible to capture all these factors and include them in an overall assessment according to an algorithm, this algorithm itself would have to be questioned. Therefore, the ultimate responsibility in this case would lie with the doctor.

Goal: Hybrid IT systems as sustainable research portfolio

The goal is thus a dynamic innovation portfolio of current IT systems that are hybrid with each other. The different bridging technologies can complement, reinforce or replace each other. In the end, however, they should be a sustainable service for us humans and this planet, also with regard to energy consumption and environmental impact.

It would be recommendable if there could be a sustainability seal for IT systems, e.g. in the form of DIN standards, as known from technology. An AI standardisation roadmap has already been proposed for Germany, in which all technical, economic, ecological, social, legal and ethical sustainability factors are included [33]. It must be clearly expressed that this type of sustainability requirement is not a brake on innovation, but rather promotes innovation, as it provides legal certainty and guidance.

5. Case study: Sustainable circular economy through digitalisation

An challenging example is the digitalisation for Circular Economy (CE) as one essential step towards achieving a more sustainable economy [34]. So far, the potential of certain digital technologies could only be shown in isolated use cases. In order to be able to comprehensively understand the potential of digital technologies for closing resource cycles, their modes of action and their interaction in socio-technical application contexts must be systematically investigated. Hereby, any socio-technical advances must be accompanied by appropriate communication strategies since they must be broadly (i) accepted by society and (ii) transferred into business models to ensure their extensive implementation.

We need a powerful digital infrastructure and digitalisation which has to be further promoted, especially in the public sector and in economy. The conversion of highly complex economic processes with high amounts of data to closed loop resource management can only be successful if these processes are supported by digital infrastructures and technology. This request seems to be a necessary condition for the realisation of CE.

Besides concrete technologies and infrastructures, the importance of standards and norms has to be taken into account. Standard and norms support the emergence of a network of technical solutions and encourage trustiness and acceptance of technology.

The already existing digital tools should be tested how far they are able to support and improve the recycling process and resource management in CE. At first, digitalisation means using basic digital tools of IT equipment, IT-supported communication and controlling which are currently not yet sufficiently available in the public sector and in many companies.

The costs and benefits in companies and public administration should clearly be addressed.

Multilateral data exchange along the supply chain and the product life cycle is needed**.** Circular economy promotes sustainable resource management, waste reduction, and the recycling or upcycling of resources. Greater transparency of product origins will help in reducing consumption and force companies to change what and how they procure resources.

Besides established IT-tools, a new promising technology such as blockchain should be applied, tested, and developed. Blockchain is a new IT-technology which can label all kinds of resources with tokens, giving them a unique digital identifier (similar to a digital coin) that people can track and trade. This makes the value of resources more apparent, facilitating a new system of pricing and trading resources, and incentivising people to adopt circular behaviours. Therefore, although many applications are still in a testing phase and need mass adoption, we ask for more research and development of blockchain in CE.

The exponential growth of computing power will accelerate the algorithmisation of economy and society. Algorithms will increasingly replace institutions and create decentralised service and supply structures. The database technology blockchain offers an entry scenario for this new digital world. It is a kind of decentralised accounting, which, e.g., replaces banks for the mediation of money transactions between customers by algorithms. This decentralised agency was invented after the global financial crisis of 2008, which was largely caused by human error in national and international central banks.

Blockchain can be presented as accounting via a continuous decentralised database. The bookkeeping is not centrally stored, but is stored as a copy on every computer of the participating actors. On each "page" (block) of the accounts, transactions between the actors and security codes are recorded until they are "full" and a new page has to be "opened". Formally, it is an expandable list of data records (blocks) that are linked with cryptographic procedures. Each block contains a cryptographically secure hash of the previous block, a timestamp, and transaction data. New blocks are created by a consensus procedure (e.g. Proof-of-Work algorithm). By the accounting system "blockchain", digital goods or values (currencies, contracts, etc.) can be reproduced at will: "Everything is a copy". After the Internet of Things, the Internet of Values (IoV) in economy is thus announced. Due to the sequential storage of data in blockchains, one-sided changes are immediately recognisable. Each actor involved would recognise changes in his copy of the blockchain, since for this the blocks linked into each other would have to be "unpacked". In addition, the high computing capacity of the entire network in "block mining" makes blockchains virtually forgery-proof. A decentralised crypto currency works in the following steps:

1. New transactions are signed and sent to all nodes of the actors.
2. Each node (actor) collects new transactions in a block.
3. Each node (actor) searches for the so-called nonce (random value) that validates its block.
4. If a node (actor) finds a valid block, it sends the block to all other nodes (actors).
5. The nodes (actors) only accept the block if it is valid according to the rules:
   a) The hash value of the block must correspond to the current difficulty level.
   b) All transactions must be signed correctly.
   c) The transactions must be covered according to the previous blocks (no duplicate output).
   d) New issues and transaction fees must comply with accepted rules.
6. The nodes (actors) express their acceptance of the block by adopting its hash value into their new blocks.

The transactions contained in the new block are initially confirmed only by the participant who created the block. They have only limited credibility. However, if the block has also been accepted as valid by the other participants, they will enter its hash value in their new blocks to be created. If the majority of participants consider the block to be valid, the chain will continue to grow fastest from this block. If they do not consider it valid, the chain will continue to grow from the previous block. Therefore, the blocks form a tree.

Only the chain longest in the first block (root) of the tree is considered valid. Thus, this form of accounting automatically consists of those blocks that have been accepted as valid by the majority. This first block, which is used to start a crypto currency, is called the Genesis block. It is the only block that does not contain a hash value of a predecessor.

The Bitcoin network, for example, is based on a decentralised database (blockchain) managed jointly by the participants using Bitcoin software, in which all transactions are listed. Instead of confidants and institutions (e.g., banks, state currency control, central banks), computationally complex and practically forgery-proof algorithms are used (e.g. proof-of-work algorithm). Proof of ownership of Bitcoin can be stored in a personal digital wallet. Bitcoin's conversion rate to other means of payment is determined by supply and demand. This can trigger speculative bubbles, which is currently still a problem for the general acceptance of Bitcoin.

In general, block chain will be an entry-level technology for a decentralised digital economy in which people as customers and citizens realise their transactions and communications directly and without intermediary institutions.

The perspective of this technology is by no means limited to banks and monetary transactions. Future developments are also conceivable, in which monitoring and controlling of recycling and other circular processes in digital economy are replaced by algorithms. What at first glance appears to be very grassroots democracy, turns out to be anything but democratic on closer analysis. The basic idea of democracy is that regardless of their position and arrival, everyone has only one vote: One man - one vote! In fact, the power of influence at, for example, Bitcoin depends on the computing power with which a customer asserts himself in the realisation of a new block: the greater the available computing power, the greater the probability and confidence that someone can solve the cryptographic task and thus guarantee security (proof-of-work).

With growing blockchain, these tasks become more and more complex and computationally intensive. But computing intensity is also energy-intensive. The fact that computation-intensive algorithms consume enormous amounts of energy is hardly considered. In November 2017, Bitcoin's computing network consumed as much kilowatts per hour as the entire country of Denmark. Therefore, countries with cheap energy and cooling for hot supercomputers can produce most Bitcoins (e.g., China). Unless countermeasures are taken and improvements made, such infrastructures in no way promise the salvation of a direct democracy, but rising energy problems (and thus growing environmental problems). In the end, digitisation depends on the overall balance of better infrastructure, less energy consumption, a better environment, and more democracy.

Besides established IT-tools, a new promising technology such as Artificial Intelligence (AI) should be applied, tested, and developed. AI opens new avenues to various aspects of sustainability: In agriculture, drones or sensor-based monitoring can be applied to assess the condition of plants in a more economic and ecological way. In production, energy consumption can be reduced through networking and robotics. Product life can be extended by means of predictive maintenance. In recycling and waste management, AI can improve the identification and sorting of waste. For building efficiency and energy management, AI offers improved system control, regulation of heating, cooling, and ventilation systems. In short: Machine learning should help to accelerate and optimise supply chains and help circulate products, components, and materials.

Up to now, the Internet has only been a database with signs and images whose meaning emerges in the user's mind. In order to cope with the complexity of the data, the network must learn to recognise and understand meanings independently. This is already achieved by semantic networks that are equipped with expandable background information (ontologies, concepts, relation, facts) and logical reasoning rules in order to independently supplement incomplete knowledge and draw conclusions. For example, people can be identified, although the data entered directly only partially describe the person.

With Facebook and Twitter, we are entering a new dimension of data clusters. Their information and communication infrastructures create social networks among millions of users. Facebook was created as a social network of universities (Harvard 2004). Social and personal data are always online. Data is by no means just text, but also images and sound documents. But, while the classic Internet only supports communication between people in global computer networks, sensor technology opens up new possibilities for the future. A new dimension of communication: commodities, products, goods, and objects of all kinds can be equipped with sensors to exchange messages and signals. The Internet of persons transforms into the Internet of Things: In the Internet of Things, physical objects of all kinds are equipped with sensors (e.g., RFID chips) to communicate with each other. This enables automation and self-organisation of technical and social systems (e.g., factories, companies, organisations). Hidden RFID and sensor technology creates the Internet of things that can communicate with each other and with people. For the Internet of Services, offers and technologies in the area of online commerce or online services and the media industry will be comprehensively expanded. Big data refers to the amount of data generated and processed on the Internet of Things. Not only structured data (e.g. digitised documents, e-mails) are recorded, but also unstructured data from sensors, which are generated by signals in the Internet of Things. The growing variety and complexity of services and possibilities in the network leads to an exponential data explosion. From petabytes (peta = 10^{15}) up, an amount of data is called Big Data.

In the digital world, according to current estimates, the global volume of data doubles every two years. Under the term "Big Data" experts summarise two aspects: on the one hand the ever faster growing mountains of data, on the other hand IT solutions and management systems with which scientific institutions and companies can evaluate, analyse, and derive knowledge from data. The industry that has developed around the collection, processing, and use of data is one in which corporations such as Google, Facebook, and Amazon are just the best-known representatives. Thousands of other companies thrive on generating, linking, and reselling information - a gigantic market. Big Data technology provides management with a significantly improved basis for time.

Big Data refers to data sets of circular economy whose size and complexity (petabyte range) is not possible due to classical databases and algorithms for collecting, managing, and processing data at manageable costs and in the foreseeable future. Three trends need to be integrated:

- massive growth of transaction data volumes (big transaction data),
- explosive increase of interaction data (big interaction data): e.g. social media, sensor technology, GPS, call logs,
- new highly scalable and distributed software (Big Data processing): e.g., Hadoop (Java) and MapReduce (Google).

Big Data initially means huge amounts of data: Google handles 24 petabytes a day, YouTube has 800 million monthly users, Twitter registers 400 million tweets a day. Data is analog and digital. They concern books, pictures, e-mails, photographs, television, radio, but also data from sensors and navigation systems. They are structured and unstructured, often not exact, but exist in masses. By using fast algorithms, they should be transformed into useful information. This means the discovery of new connections, correlations, and the derivation of future prognoses.

However, forecasts and maintenance of products are not necessarily extrapolated on the basis of representative samples using conventional statistical methods. Big data algorithms evaluate all data in a data set, however large, diverse and unstructured they may be. What is new about this evaluation is that the contents and meanings of the data records do not have to be known in order to be able to derive information.

This is possible by so-called metadata. What this means is that we do not need to know what someone is talking about on the phone, but the movement pattern of their mobile phone is decisive. A precise movement pattern of the mobile phone user can be determined over a certain period of time from a data retention memory, since the local radio cells are switched on with every automatic e-mail query and another use. The data in an e-mail refers to the text of the content. Metadata of the e-mail are, e.g., sender, recipient, and the time of sending. In the immersion project of the Media Lab of the MIT (Massachusetts Institute of Technology), graphs are automatically drawn from such metadata. In an earlier experiment at MIT, motion patterns of 100 people had been determined over a recording period of 450,000 hours. This made it possible to determine who met whom and how often at certain locations. Places were grouped as workplace, home and others. On the basis of corresponding patterns of metadata, economic and ecological networks could be supervised with a high probability.

Often, however, predictions can only be derived from metadata if the correct contexts are known. Today, however, there are databases and background information on the Internet with which the meanings can be made accessible. In principle, this development of meanings works like a Semantic Web. The discovery of an American bioinformatician who used metadata alone to determine the name of an anonymous donor of human genetic material was spectacular. Metadata related to the age of the donor and the name of the American state in which the donation was made. The bioinformatician limited the search by combining place and age and used an online search engine in which families entered the genetic code for genealogical research. In the process, family members of the wanted persons emerged, whose data she combined with demographic tables, in order to finally find what they were looking for.

As long as the causal causes of a data correlation are not known and not understood, the mass evaluation of data and the calculation of correlations only help to a limited extent: "Correlation is no causation!"

Thus, predicative modelling is the central goal of Big Data mining as part of data science. Algorithms of machine learning are used for this purpose which enable self-improving and self-repairing of production cycles. We rely more and more on efficient algorithms, because otherwise the complexity of our economic infrastructure would not be manageable: Our brains are too slow and hopelessly overwhelmed by the amount of data we have to deal with. But how secure are AI algorithms? In practical applications, learning algorithms refer to models of neural networks, which themselves are extremely complex. They are fed and trained with huge amounts of data. The number of necessary parameters explodes exponentially. Nobody knows exactly what happens in these "black boxes" in detail. A statistical trial-and-error procedure often remains. But how should questions of responsibility be decided in, e.g., autonomous car driving or circular economy, if the methodological basics remain dark? In machine learning with neural networks we need more explanation (explainability) and attribution (accountability) of causes and effects in order to be able to decide ethical and legal questions of responsibility!

It is crucial to develop sustainable business models that are based on Circular Economy-approaches. There are already promising case studies for Circular Economy through digitalisation: Examples which we considered carefully concern sustainable urban housing, sustainable smart city, metallurgical recycling potentials, and recycling processes of plastic.

The environmental, economic and societal balance of digital tools and infrastructures, i.e. their ecological, economic, and societal effects in Circular Economy is decisive. For example, efficiency of digital applications and their economic and ecological costs of energy consumption must be balanced to improve the benefits of a circular economy.

The traceability of products and product properties across the value chain and the product life cycle is becoming an increasingly important success factor for industry. Digital product passports offer great potential here, as they allow specific product data to be made available. This makes it possible to transparently determine and present both the requirements demanded by political regulation and those increasingly in demand on the market with regard to the ecological and social footprint of a product. Digital product passports can be particularly helpful in industrial sectors with high resource consumption and recycling challenges, e.g. electronic devices, batteries or cars.

Finally, the following theses is recommended: We need a powerful digital infrastructure and digitalisation which has to be further promoted, especially in the public sector and in European companies. Besides established IT-tools, new promising technologies such as blockchain and AI should be applied, tested, and developed. The environmental, economic and societal balance of digital tools and infrastructures, i.e. their ecological, economic, and societal effects in CE is decisive to achieve a more sustainable economy.

6. Concluding remarks: Sustainability, law and innovation in the competition value systems

Europe must not only be a leader in innovation, but also build an attractive societal environment to go with it. Protection of individual liberties and secure social systems in a market economy remain high goods, even in the age of energy, information and communication technology, which are recognised and valued by all people worldwide.

Europe was not only the birthplace of science and technology in the times of industrial revolution during the 18th and 19th century, which led to worldwide innovation dynamics in the age of globalisation. Europe also created a unique cultural area based on democracy and human rights. This spirit of the European cultural area must be combined with the dynamics of the European innovation area in order to remain an attractive place to live in the future. In concrete terms, the world of work and life will change dramatically under the influence of artificial intelligence and big data.

Europe must therefore create the framework conditions for education and training systems so that career and life opportunities are opened up and promoted for young people in Europe in the age of digitalisation and ecological crisis. In the end, however, Europe must also secure the ethical and legal framework conditions (e.g. privacy, cybersecurity) to shape these future technologies in such a way that freedom, human rights and democracy are preserved as the hallmarks of Europe.

Modern technologies of the future open up new opportunities to improve sustainable life, but also to revert to past patterns of behaviour with incalculable consequences.

The protection of and respect for human dignity by the state and legislators are therefore indispensable. Europe must build on this. Normative claims, however, only become legal norms if they can be enforced. For this, Europe must be ecologically, economically, politically, and militarily strong - through innovation.

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